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Report on Geophysical Surveys at Four Inactive Waste Burial Sites in the 1100-EM-1 Operable Unit

Prepared for the U.S. Department of Energy
Assistant Secretary for Environment, Safety and Health

Westinghouse
Hanford Company Richland, Washington

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

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G. A. Sandness
E. V. Allen
D. K. Larson
Pacific Northwest Laboratory

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REPORT ON GEOPHYSICAL SURVEYS
AT FOUR INACTIVE WASTE BURIAL SITES IN THE
1100-EM-1 OPERABLE UNIT

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1.0 INTRODUCTION

This report describes a set of geophysical surveys performed by the Automation and Measurement Sciences Department of the Pacific Northwest Laboratory (PNL) at four hazardous waste burial sites in the 1100-EM-1 Operable Unit at Hanford. The surveys were performed for the Westinghouse Hanford Company (WHC) as a task under the Hanford Inactive Waste Sites Evaluation Program and were performed in accordance with a work plan outlined in a Statement of Work dated December 12, 1988. The work itself was performed during the months of January through April, 1989.

This is the second of three primary products, or deliverables, that are to be submitted to WHC by PNL during the course of this study. The first of these products was a procedures document which we submitted to WHC prior to the initiation of field work.* A copy of this document is included as the Appendix of this report. The third product consists of copies of the field notebooks and the geophysical data collected in this study. This assortment of materials will be submitted to WHC within two weeks. The data will be provided in the form of 9-track magnetic tapes.

The text in the remainder of this report is divided into five sections. Section 2 provides a brief introduction to the four sites that were included in this study. Section 3 outlines the objectives of the geophysical surveys. Section 4 briefly describes the geophysical methods. Section 5 discusses the results of the geophysical surveys for each of the four sites. Section 6 contains some final comments relating to the quality of the results and the value of ground truth data.

2.0 SITE DESCRIPTIONS

Figure 1 shows the general locations of the four sites which we surveyed by geophysical sensing methods. Brief descriptions of these sites are as follows:

1) Battery Acid Pit (Site 1100-1). This site is reported to contain a small pit, now backfilled and leveled, which was used as a disposal facility for waste battery acid between 1954 and 1977. The assumed location of the pit is shown in Figure 2.

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* G. A. Sandness, "Procedures for Geophysical Site Surveys, 1100-EM-1 Operable Unit," January, 9, 1989.

2) Paint and Solvent Disposal Pit (Site 1100-2). This pit was utilized as a disposal site for solvents, paints, and paint thinner during the period 1954-1985. As shown in Figure 3, the pit is divided into two parts by a railroad track embankment. Concrete and asphalt rubble is visible at the ground surface in the larger part.

3) Antifreeze and Degreaser Pit (Site 1100-3). Antifreeze, degreasers, and other materials were deposited in this pit between 1979 and 1985. The apparent size of the pit as shown in Figure 3 is considerably larger than that of the original pit because of a recent landscaping operation which moved ground materials from the sides of the pit toward its center.

4) Horn Rapids Landfill. This site was apparently used for the disposal of a variety of waste materials, including office and construction wastes, tires, asbestos, and liquid chemicals. Most of the disposal activity at this site is thought to have occurred prior to 1970. The location and shape of the site are shown in Figure 4.

The last three of these sites are apparently shallow sand/gravel borrow pits that were utilized as waste disposal sites as a matter of convenience. At Sites 1100-2 and 1100-3, the waste materials were simply dumped into the bottoms of the pits and eventually covered by available ground materials. At the Horn Rapids Landfill, several waste disposal pits and trenches were excavated in the floor of the borrow pit. With two exceptions, these pits and trenches have been filled and leveled and are now difficult or impossible to discern by visual observation. One of the exceptions is an unfilled segment of a marked trench in which asbestos waste materials have been buried. The other exception is an open pit containing a large number of rubber tires.

3.0 OBJECTIVE

The basic objective of the geophysical surveys was to obtain information about the location of the buried waste materials, subsurface waste disposal structures (e.g., trenches and pits), underground utilities, and other waste-related subsurface features that might be present within the boundaries of the survey area at each site. This information is needed to characterize the sites and to guide the selection of specific locations for subsequent sampling, drilling, and excavation activities.

The specific objective at Site 1100-1 was to locate the small battery acid disposal pit and any underground pipes or cables that may be present in the vicinity of the pit. This required a relatively detailed survey with closely spaced traverse lines. Because the other three sites are much larger, the work plan called for the use of more widely spaced traverse lines. Our survey objective at these three sites was to perform a set of reconnaissance surveys that would be expected to detect and map the major deposits of buried waste materials, but which might not detect small deposits such as individual 55-gal drums. Specific details regarding the spacing of traverse lines, measurement procedures, and other aspects of the geophysical surveys are presented in Sections 4 and 5.

4.0 GEOPHYSICAL SURVEY METHODS

To accomplish the objectives outlined above, we utilized four distinct geophysical sensing methods. These were: 1) metal detection, 2) electromagnetic induction (EMI) ground conductivity measurements, 3) magnetometry, and 4) ground-penetrating radar (GPR) profiling. The sensors and procedures that correspond to these methods are described briefly in the following paragraphs. Additional instrument specifications and operational details have been presented in a procedures document contained in the Appendix.

4.1 METAL DETECTION

The metal detector used in this study was a Fisher TW-6 M-Scope. This instrument operates on the induction balance principle. Two loop coils (one for transmitting and one for receiving) are geometrically arranged in such a way that a null condition is obtained in the absence of nearby metallic objects. When the coils are properly adjusted, the receiver is insensitive to the magnetic field of the transmitter. However, a signal is detected if the magnetic field at the receiver coil is altered by a secondary magnetic field resulting from induced electric currents in a nearby metallic object or conductive body. Deviations from the balance condition are detected as electrical signals in the receiver and are electronically converted to a meter deflection and an audible tone change.

This type of instrument is an analog device which requires a subjective data interpretation by the operator. It is normally used in a reconnaissance mode to outline the general distribution of metallic waste materials at a waste burial site. It is a relatively inefficient device for detailed surveys of large areas because it requires the operator to actively respond to its indicator signals. Its sensitivity is such that one would expect to detect a single 55-gal drum at a depth of 3-6 ft.

4.2 MAGNETOMETRY

This method is based on the fact that an induced magnetization is produced in any magnetic material within the earth's magnetic field. The induced field is superimposed on the earth's magnetic field and can be detected as an anomaly in the ambient field. In these surveys, we used a Varian VIW2302C1 cesium vapor magnetometer which measures the total magnetic field, or the magnitude of the magnetic field vector.

Magnetic measurements are most effective in locating buried steel objects such as the 55-gal drums commonly used to store chemical and radioactive waste materials. A large concentration of steel drums buried at a typical waste burial depth (0-30 ft) will produce a large, easily detectable anomaly. A single drum or other relatively small steel object will produce a smaller anomaly and might not be detectable if it is deeply buried or if it is located in a magnetically noisy environment.

4.3 EMI GROUND CONDUCTIVITY MEASUREMENTS

The Geonics EM31 ground conductivity meter which we used in these surveys is a portable instrument that uses the electromagnetic induction principle to measure the apparent electrical conductivity of the ground. This instrument contains two coils mounted at opposite ends of a 12-ft long support tube. An alternating magnetic field produced by the transmitter coil induces electrical currents in the ground and in any conductive waste materials that may be present in the ground. These currents, in turn, produce a secondary magnetic field that is detected by the receiver coil. The ratio of the secondary and primary field components is measured and electronically scaled to derive the desired conductivity value. The resulting analog signal is displayed to the operator by means of a meter on the unit's control panel. An electrical output connector permits the signal to be recorded by an external data logger.

4.4 GROUND-PENETRATING RADAR PROFILING

The ground-penetrating radar system used in these surveys was a SIR System 7 manufactured by Geophysical Survey Systems, Inc. It operates by transmitting a short (5-nsec) electromagnetic pulse into the ground, then detecting the signals that are backscattered or reflected from buried objects or interfaces. In principle, reflected signals are produced by any object (metallic or nonmetallic) or interface that has a dielectric constant or electrical conductivity different from that of the surrounding earth. Examples of detectable targets include metal or plastic waste containers, metal and plastic pipe, sand and clay layers or lenses, bedrock, and the edges of backfilled trenches. The radar operates in the time domain reflectometry mode where the depth of a reflective target or interface is proportional to the travel time of the reflected signal. The maximum effective penetration depth of the system is approximately 20-25 ft in the near-surface sand and gravel sediments that are present at the sites surveyed in this study.

4.5 DATA COLLECTION PROCEDURES

The area to be surveyed at each site, except the Battery Acid Pit, was defined by a grid emplaced by Kaiser Engineers. Each grid consisted of an orthogonal set of lines marked by wooden stakes at the intersections of the lines. Because of the small size of the Battery Acid Pit site, the task of establishing a survey grid at that site was left to PNL. Before performing the geophysical surveys at that site, we established the required grid by measuring distances with a steel tape and marking line locations with spray paint. To ensure that the grid boundaries could be relocated later, we also marked the four corners with steel pins. The following table gives the grid dimensions at the four sites and summarizes the geophysical surveys in terms of the types of measurements that were made, the spacing of the traverse lines, and the traverse directions for each of the geophysical survey methods. Each of the grids was square in the sense that the grid lines, or the stakes, were equally spaced in both orthogonal directions.

SITE	GRID LINE SPACING (ft)	TRAVERSE LINE SPACING (ft)	SURVEY METHOD (DIR)
Battery Acid Pit (1100-1)	5	2.5 N-S 5 E-W	Met Det. (N-S, E-W) Magnetometer (N-S)
Paint and Solvent Disposal Pit (1100-2)	40	40 NE-SW 10 SE-NW	Met. Det. (NE-SW, SE-NW) Magnet. (NE-SW) EMI (NE-SW, SE-NW) GPR (NE-SW)
Antifreeze and Degreaser Pit (1100-3)	40	40 N-S 10 E-W	Met. Det. (N-S, E-W) Magnetometer (N-S, E-W) EMI (N-S, E-W) GPR (N-S, E-W)
Horn Rapids Landfill	100	100 N-S 100 E-W	Met. Det. (N-S, E-W) Magnetometer (N-S) EMI (N-S, E-W) GPR (N-S, E-W)

The basic procedure for data collection at each site was to separately carry or pull the four geophysical sensors along straight traverse lines coincident with, or parallel to, the stake lines of the survey grid. As indicated in the above table, the spacing of some of the traverse lines was less than the spacing of the grid lines. The locations of these lines were determined by measurements from the closest grid stakes. The metal detector, magnetometer, and conductivity meter were all carried by the operator. The GPR system was transported by a small all-terrain vehicle which contained the radar control unit and other electronic components needed to digitize and record the radar signals.

The magnetometer and EMI data were collected along traverse lines at a normal walking speed, yielding an along-track data spacing of approximately 12 inches. The GPR data were collected with approximately the same traverse speed, but with a higher data collection rate, yielding an along-track data spacing of approximately 5 inches. Both types of data were recorded in digital form by means of a small, battery-powered data recorder.

To ensure that the collected data could be accurately associated with the grid coordinates, the operator of the magnetometer and the EMI conductivity meter walked at a constant speed along the survey lines. In addition, each time the operator crossed a grid line, he pressed a switch which entered a marker code into the data record. These markers provided fixed points within each data record at which the locations of the measurements were precisely known. Thus, the worst-case location uncertainties for the magnetometer and EMI measurements were approximately 1 ft.

Location information for the GPR data was provided by an angle encoder, or footage counter, mounted on the axle of the all-terrain vehicle. The output of this counter was digitally recorded along with the radar data. The resulting uncertainty in the along-track coordinate of the radar data was approximately 2 ft.

The metal detector was operated by carrying it along a traverse line until a buried metallic object or deposit was detected. At that point, the operator painted a line on the ground to indicate the location of the object, then extended the search laterally to attempt to find a closed boundary around the buried material. Because of the relatively small size of Sites 1100-2 and 1100-3, it was possible to outline all of the detected metallic materials at those sites. On the other hand, the large size of the Horn Rapids Landfill made it impractical to complete the outlines of some of the largest metallic deposits present at that site.

4.6 DATA PROCESSING PROCEDURES

We initially recorded the results of the metal detector surveys by painting lines directly on the ground. These lines corresponded to the boundaries of the detected metallic waste materials. Their locations were subsequently recorded in a field notebook and were ultimately transferred to final site maps. No other processing of the data was required.

All of the magnetometer and EMI data sets were recorded by means of a portable digital data logger as described above. Thus, all of these data sets, or files, had the same format and could be processed in the same way. The first step in the data processing procedure involved a linear interpolation of the data to adjust the along-track data spacing to a predetermined value. This value was set at 1 datum/ft for all of the magnetic and EMI surveys. The accuracy of the interpolation algorithm was enhanced by utilizing the marker codes in the data records to divide the data file into segments corresponding to the distance between stakes. Thus, each end of a 40-ft or 100-ft data interval was precisely correlated with the known location of a row of stakes in the survey grid.

The second step in the processing of the magnetometer and EMI data sets was the production of graphs (enclosed) showing the amplitude of the recorded signal as a function of distance along the survey lines. As a final step, these graphs, or profiles, were visually interpreted to determine the locations of the buried waste materials. The results were plotted on a series of site maps which constitute the final products of the magnetic and EMI surveys.

The GPR data were initially recorded on digital tape cartridges. These tape files were transferred to the hard disk of a DEC 11/23 minicomputer. Associated with each data file was a descriptor file which contained information such as the number of digitized data in each received signal (scan), the number of scans in each traverse, and the nominal length and direction of each traverse. The first step in processing a given data set was to edit the descriptor file, modifying the parameters as needed to correspond to the actual values (e.g., the actual track length may differ from the nominal track length that was initially recorded). Using the parameters of the edited descriptor file, the data file was then interpolated by a linear method equivalent to that used to interpolate the magnetic and EMI data. This procedure yielded data sets that contained a predetermined number of scans per unit length. In this study, the data density was set at 2.5 scans/ft for the three large sites, and at 4 scans/ft for the Battery Acid Pit. The interpolated files were written to 9-track magnetic tape for long-term storage and to facilitate the transfer of the data to a VAX computer. This computer was used to perform the final data processing and display operations.

The last data processing step involved the removal of unchanging signal components from the radar data. These unwanted components consist of reflections from the ground surface, from within the radar system, and from external objects such as the survey vehicle. In a video or photographic display of the radar data, these components appear as horizontal stripes that extend from one end of the traverse to the other. They were removed from the data files by computing an average amplitude at each depth increment, or row in the two-dimensional data set, then subtracting that average from each datum in the row. Eliminating the largest positive and negative data from the average prevented the average from being biased by exceptionally strong localized reflections.

Hardcopy images of the radar data (profiles) were produced with the aid of a Dicomed D47 digital film recorder. A set of photographic prints showing these profiles in the form of intensity-modulated black and white images is appended to this report. Each image in these prints corresponds to a complete or partial survey line, depending on the length of the line (the film recorder was capable of displaying the data for only an 800-ft long line segment). Profiles corresponding to lines longer than 800 ft were continued on successive pages with the along-track coordinates appropriately labeled. The horizontal dimension in each profile corresponds to distance along the survey line. The vertical dimension corresponds to the two-way travel time of the radar signals or, equivalently, to the depth of the reflective materials. Estimated depth scales are shown on several of the photographic pages. These depth scales were calculated from previously determined values of the relative dielectric constant of the ground materials at other Hanford sites. They can be easily adjusted if excavations at the current sites show that the actual depths of buried objects are different from the depths given on the radar profiles.

Because the radar waveforms oscillate between positive and negative values, the amplitude modulation was adjusted to display large negative data values as black and large positive values as white. The presence of a reflective buried object is usually indicated by a hyperbolic pattern of white and black tones. For a concentration of reflective objects, the reflection pattern may be quite complex; however, such a pattern is usually distinctive and distinguishable from the more regular or subdued patterns produced by undisturbed ground.

The following table summarizes the plots and photographs that display the collected data.

SITE	DATA DISPLAY PRODUCT
Battery Acid Pit (Site 1100-1)	Magnetic profiles, none EMI profiles, none GPR profiles (photographs), 3 pages
Paint and Solvent Disposal Pit (Site 1100-2)	Magnetic profiles, 7 pages EMI profiles, 10 pages GPR profiles (photographs), 4 pages
Antifreeze and Degreaser Pit (Site 1100-3)	Magnetic profiles, 9 pages EMI profiles, 10 pages GPR profiles (photographs), 5 pages
Horn Rapids Landfill	Magnetic profiles, 7 pages EMI profiles, 12 pages GPR profiles (photographs), 16 pages

Note that the vertical axes of the magnetic profiles have units of gammas, where 1 gamma = .00001 gauss. The amplitude of the ambient (natural earth's) magnetic field has been subtracted, leaving only the residual values produced by buried waste materials and by natural variations in the magnetic properties of the ground. The numbers shown on the vertical axes of the EMI profiles are the raw data values produced by the 12-bit analog-to-digital convertor in the data logger. Multiplying these numbers by .005 yields the approximate value of the electrical conductivity of the ground in units of mmhos/m, but the resulting values are meaningful only in areas where the ground is relatively undisturbed and are not related in any simple way to the properties of the buried waste materials. All of the useful information relating to the distribution of waste materials is contained in the raw, or relative, data values shown on the profiles.

The horizontal axes of the magnetic, EMI, and GPR profiles show distances in units of feet along the survey lines. The location and direction of each profile are indicated by labels printed on the profile. To understand these labels, refer to the site maps (discussed below) which show the survey grids. The combination of labels and maps should make it easy to locate the starting and ending points of the profiles. The origin of the SW-NE EMI profiles at Site 1100-2 requires further explanation, however. In these profiles, the zero coordinate corresponds to grid line 1E, and the profiles cover only the eastern segment of the site.

5.0 RESULTS

We derived the locations of the buried waste materials at each site by visually interpreting the magnetic, EMI, and radar profiles. The results are shown on the enclosed set of 11 site maps. Three maps (numbered 1-3) are included for Site 1100-2. Map 1 shows the GPR and metal detector results; Map 2 shows the magnetic and EMI results; and Map 3 shows our interpretation of the combined data sets. Three similar maps (4-6) are included for Site 1100-3. Only one map (Map 7) is included for the Battery Acid Pit because the surveys at that site were limited to the GPR and metal detector methods. Four maps (8-11) are provided for the Horn Rapids Landfill. Map 8 shows the major topographic features at the site as plotted by eye during a walking inspection of the site. The information shown on this map was essential to the interpretation of the geophysical data. The other three maps (9-11) show the results of the geophysical surveys.

5.1 BATTERY ACID PIT (1100-1)

The dimensions of the survey grid that we established for our GPR survey of this site were 70 ft N-S by 60 ft E-W (see Map 1). These dimensions were sufficiently large to cover the area in which the pit was assumed to be located. Because the diameter of the pit was reported to be only 5-12 ft, we collected data along a set of survey lines spaced only 2.5 ft apart in the north-south direction and 5 ft in the east-west direction.

The radar profiles produced from the data collected at the site proved to be complex and difficult to interpret. A general characteristic of the site is that much of the ground within the area covered by the survey grid appears to have been excavated and backfilled. Consequently, the radar reflection patterns associated with the battery acid disposal pit would not be as unique or distinctive as they would be if the pit were located in an otherwise undisturbed area. Map 1 shows the locations of the major subsurface features that were discernable in the profiles. These include apparent trench boundaries, pipes, possible cables, anomalous reflective interfaces, and isolated metallic objects. The numbers associated with some of the features shown on the map are the estimated depths of the features in units of feet.

A water pipe is present at a depth of approximately 4 ft at the north end of the survey area. This pipe supplies water for a shower that is located at coordinates 25S,30W. Five other possible pipe or cable segments are also shown on the map. An apparent trench boundary is located roughly along Line 50W. The north end of this boundary seems to turn toward the east at coordinate 25S. Another possible trench boundary is located along Line 30W, between coordinates 50S and 65S. The crosshatched patterns on the map show the locations and approximate shapes of strongly reflective interfaces or surfaces that may correspond to subsurface structures or, at least, to features related to the excavation of the site. One of these patterns might correspond to the battery acid disposal pit, but it may not be possible to determine this without additional information. Drilling or digging at these locations would provide a great deal of information and could succeed in locating the pit, but would involve some potential hazard. Additional GPR measurements, utilizing a higher-resolution radar antenna, might also be helpful. The current survey was performed with a nominal signal frequency of 300 MHz to achieve a balance between spatial resolution and depth of penetration. The results of that survey indicate that a frequency of 600 MHz would provide improved resolution with adequate penetration.

5.2 PAINT AND SOLVENT DISPOSAL PIT (1100-2)

The results of the geophysical surveys at this site are shown on Maps 2, 3, and 4. Map 2 shows the location of waste materials as determined from the GPR and metal detector surveys. Map 3 shows the equivalent results derived from the EMI and magnetic surveys. The information contained on both of these maps was combined and evaluated to produce Map 4, which represents our final interpretation of the geophysical data at this site.

The survey grid to which the geophysical data are referenced is shown on each of the maps. This grid includes 26 stakes that we added to the periphery of original grid that was surveyed and marked by Kaiser Engineers. The additional stakes extended the geophysical surveys outside the apparent boundaries of the pit, thereby providing a form of background data against which the data from the pit itself could be compared. The size of the enlarged survey area was 2.7 acres.

Reflections from a soil interface that appears to mark the bottom of the original pit are visible on Pages 2 and 3 of the GPR profiles from this site (1100-2). The estimated maximum depth of this interface (and the maximum thickness of the waste materials) is approximately 10 ft. The deepest point of the original pit is located approximately at coordinates H,2E+20 (i.e., on grid line H, 20 ft east of the 2E line). Most of the buried waste materials are covered by no more than 2 ft of soil; however, the soil cover seems to be 5 or 6 ft thick in the vicinity of coordinates G,4H.

As shown on Maps 2-4, most of the waste materials are concentrated in an irregularly shaped mass which fills a major part of the eastern section of the pit. There is no evidence of a waste deposit in the western section of the pit (west of the railroad track). Much of the waste material seems to be concrete and asphalt rubble. This is suggested by the fact that these types of material are visible at the ground surface in the pit. In addition, the relatively low amplitude of the magnetic anomalies measured over the waste deposits is about what one would expect to be produced by concrete rubble with scattered pieces of steel rebar. Although there is almost certainly no large deposit of 55-gal drums at this site, some metallic or non-metallic containers of hazardous chemicals may be present. Also, the geophysical sensors have no ability to detect chemicals that may have been poured into the soil.

The only other significant features at this site are several irrigation pipes. One of these, located at the north end of the survey area, originates just to the west of the railroad track and can be traced to the east at least as far as Stevens Drive. Another underground pipe is located under the powerline at the west edge of the site. Several scrap pieces of metal irrigation pipe and a short section of a wire-wrapped wooden irrigation pipe are located in the southwest corner of the site.

5.3 ANTIFREEZE AND DEGREASER PIT (1100-3)

The survey grid for this site is shown on Maps 5-7. This grid includes 19 stakes that we added to the original grid marked by Kaiser Engineers. The size of the final grid, or survey area, was 3.7 acres.

Map 5 shows the locations of waste materials detected by the GPR and metal detector surveys. Map 6 shows the equivalent results for the EMI and magnetometer surveys. Map 7 shows the locations of the waste deposits as determined from the combined results of all four geophysical surveys.

The waste materials appear to be concentrated in one large deposit and two small satellite deposits. Small pieces of debris are also scattered around the site. As at Site 1100-2, the buried waste materials contain a substantial amount of steel, but do not appear to include a large number of steel drums. Although the ground surface has been largely covered by soil and gravel, some concrete rubble is visible. Therefore, it is likely that some of the magnetic material is rebar. The geophysical data do not provide enough information to justify additional conclusions regarding the composition of the waste materials.

An irrigation ditch and a set of underground pipes connected to a concrete diversion box were apparently present at this site prior to the excavation of the original gravel pit. A remnant of the ditch is visible to the north of the access road and remnants of the tile pipes are visible near the diversion box in the northeast corner of the site. The pipes were also detected by the geophysical instruments, particularly the EMI sensor. Their general location is indicated on Map 6.

5.4 HORN RAPIDS LANDFILL

At this site, we added only four stakes to the original survey grid established by Kaiser Engineers. These were located at the extreme north end of the site. The size of the final gridded area was 61 acres.

It is apparent that this site was originally a large sand/gravel pit. The dune sand and some of the underlying gravel were removed over a large area. Subsequently, several trenches and pits were excavated for the burial of waste materials, some of which were hazardous. In other parts of the site, waste materials were burned and liquid wastes were apparently allowed to drain into the soil. Map 8 shows much of the outline of the original gravel pit. It also shows the open end of a waste burial trench (labeled T), a deep open pit (P), two shallow depressions (D), and several gravel piles (GP).

Map 11 shows the combined results of all four geophysical surveys. Because of the wide spacing of the survey lines, there is considerable uncertainty as to the shapes and sizes of the buried waste deposits. Nevertheless, we have drawn the boundaries of the trenches and pits as they are defined by the available geophysical data. The boundary lines are dashed where their correct location seems to be particularly uncertain.

A general result shown by Maps 9-11 is that the waste deposits are concentrated in an area of approximately 17 acres in the south central part of the site. The largest waste burial feature is a long, SSE-NNW-trending trench shown at the south ends of lines G-J. This trench is reported to contain asbestos wastes and is marked by warning signs. Visual observation suggests that the open excavation marked T on Map 8 represents the unused north-northwest end of this trench. This would imply that the waste deposit extends from approximately J,2 to H,5. The geophysical data indicate, however, that the trench and the corresponding waste deposit actually extend at least 300 ft further to the north-northwest (i.e, from J,2 to approximately G,7). In other words, the trench is approximately 600 ft long and includes a partly filled segment located just to the north-northwest of coordinate H,5.

Three smaller trenches are located to the east of this first trench. The axes of these trenches are also oriented approximately in the SSE-NNW direction. It is not clear whether the tire disposal pit located at coordinates H-J,7-8 is a separate excavation or an open extension of the small trench that is located close to the south end of the pit.

Four oval-shaped waste deposits are located in an area bounded on the N-S lines M and T and by the E-W lines 1 and 8. For the most part, these deposits seem to be close to the ground surface and only a few feet thick. In contrast, the deposits in the trenches described above seem to extend to a depth of 18 ft or more. Another relatively shallow waste deposit is located at the north end of the site approximately 100 ft east of the burning cage (coordinates M,15-16.5).

The geophysical data do not show any other major deposits of waste materials at this site. There is, however, debris such as paint cans, steel cable, sheet metal, concrete rubble, and miscellaneous junk scattered over much of the site. The locations of some of the larger pieces of this type of material are shown on Map 11.

6.0 FINAL COMMENTS

The geophysical surveys described in this report appear to have successfully detected and mapped the major deposits of waste materials at Sites 1100-2 and 1100-3. Although these surveys should be regarded as reconnaissance in nature, the results can probably be regarded as reasonably definitive; only small, isolated objects are likely to have been missed. The surveys of the Horn Rapids Landfill were also very effective, but it should be understood that because they were performed on a much coarser grid, the resulting map is highly generalized and substantial waste deposits may remain undetected. The survey of the Battery Acid Pit was much less satisfactory in the sense that the location of the pit could not be clearly identified. Ground-truth data acquired by drilling or excavation will be of particular value at this site, but similar data at the other sites would also be useful. In particular, ground-truth information would provide a means to refine our interpretations of the data that have already been collected and to add a degree of sophistication and confidence to the interpretation of data collected in future surveys. The feedback of ground-truth data to the geophysical survey personnel is an important aspect of a site investigation effort.

Finally, we would like to caution the reader that the current state of the art in geophysical survey technology cannot ensure 100% accuracy in the detection of hazardous materials or in the interpretation of the collected data. Thus, it is not generally feasible to uniquely identify detected waste materials or even to characterize those materials as hazardous or non-hazardous. The results of the geophysical surveys will reduce, but will not eliminate, the risks that are associated with subsurface sampling, drilling, and excavating at these sites.

FIGURES

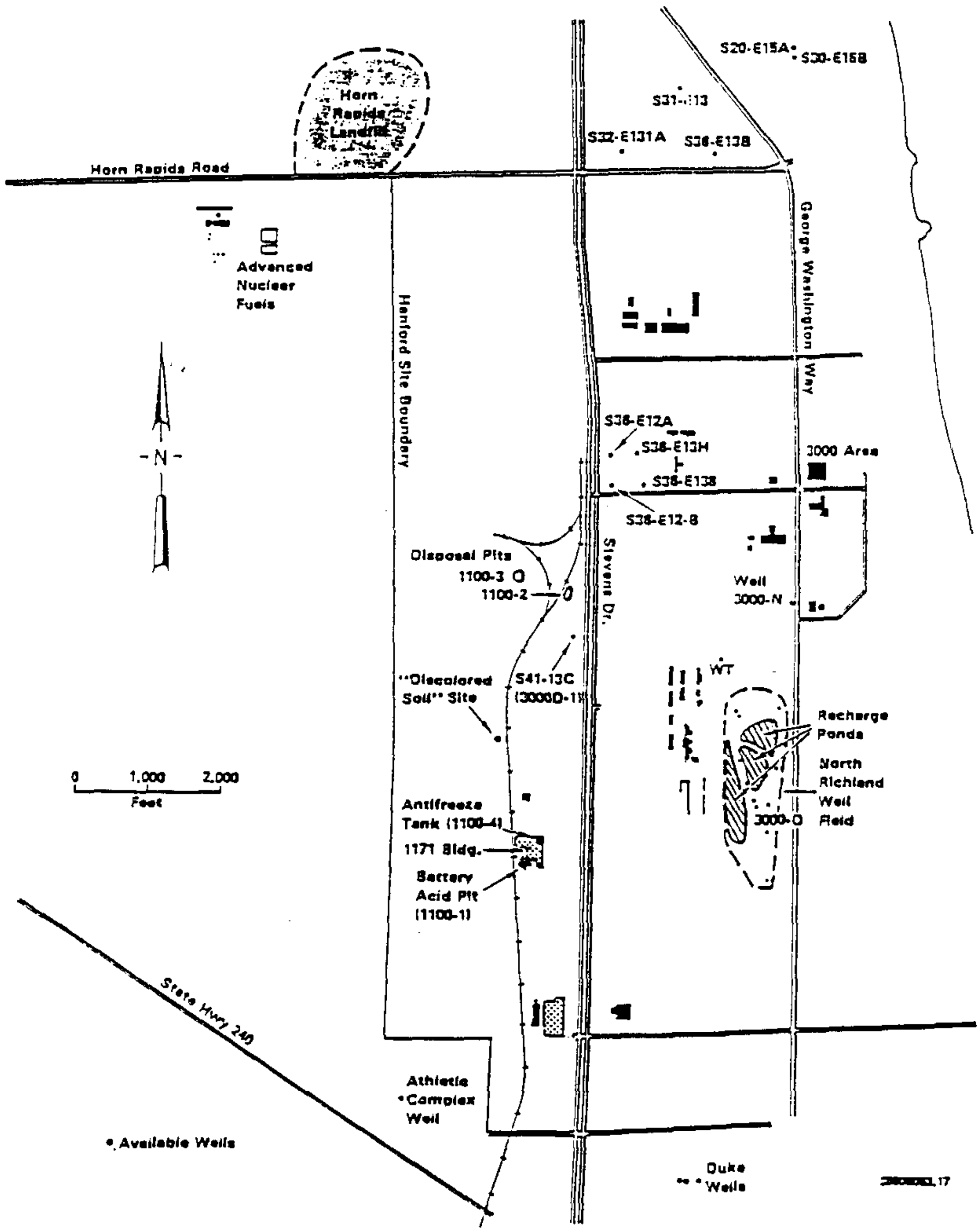

FIGURE 1. Waste site locations.

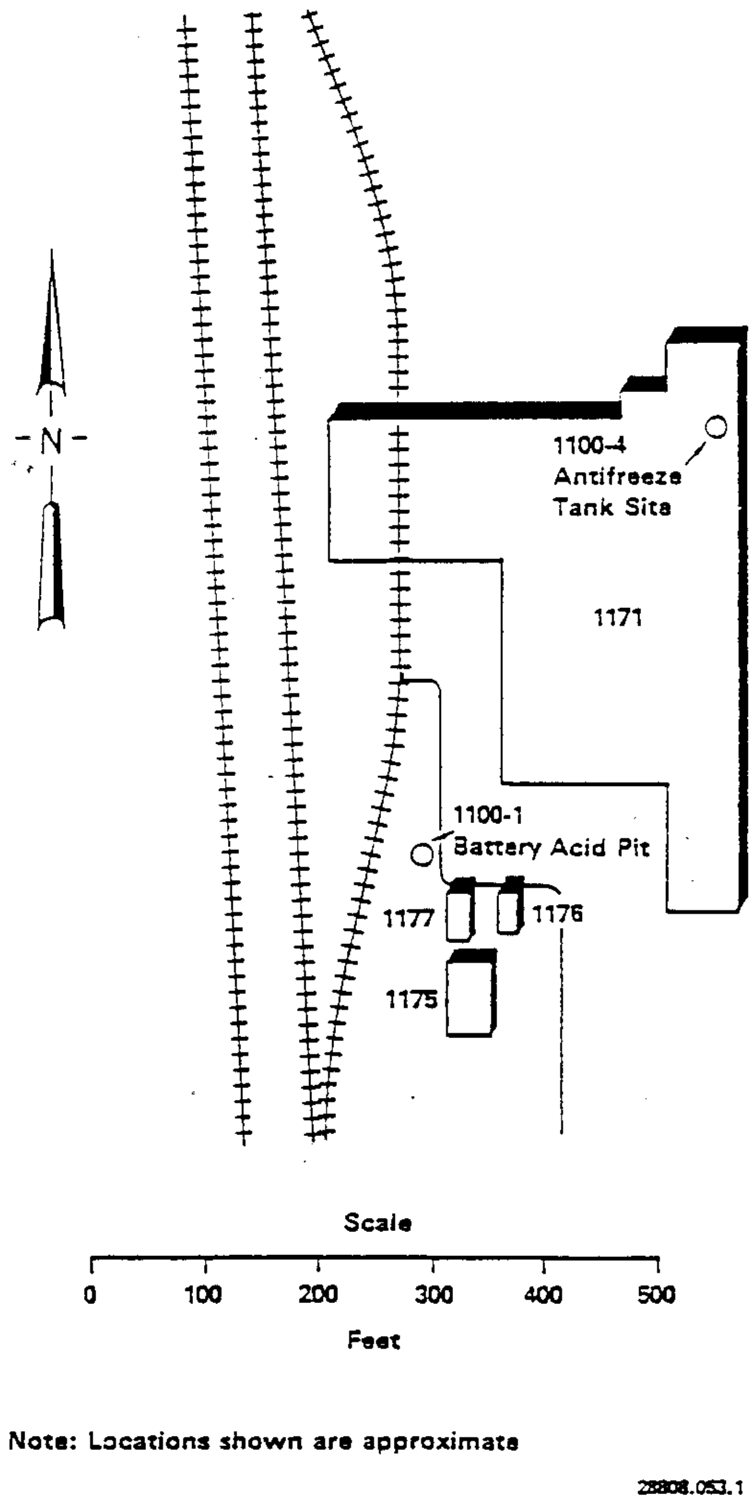

FIGURE 2. Location of battery acid pit.

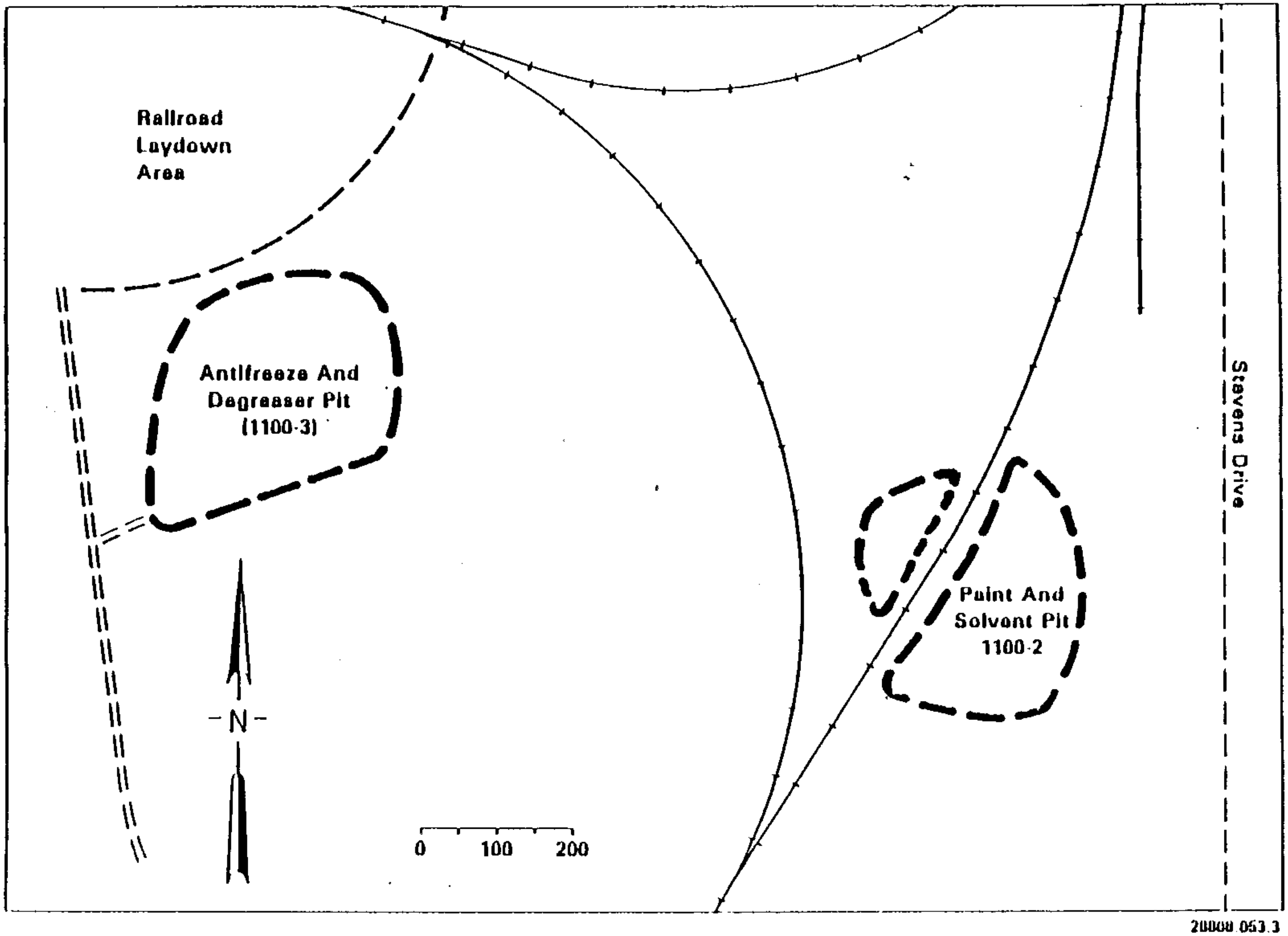

FIGURE 3. Approximate pit boundaries at sites 1100-2 and 1100-3.

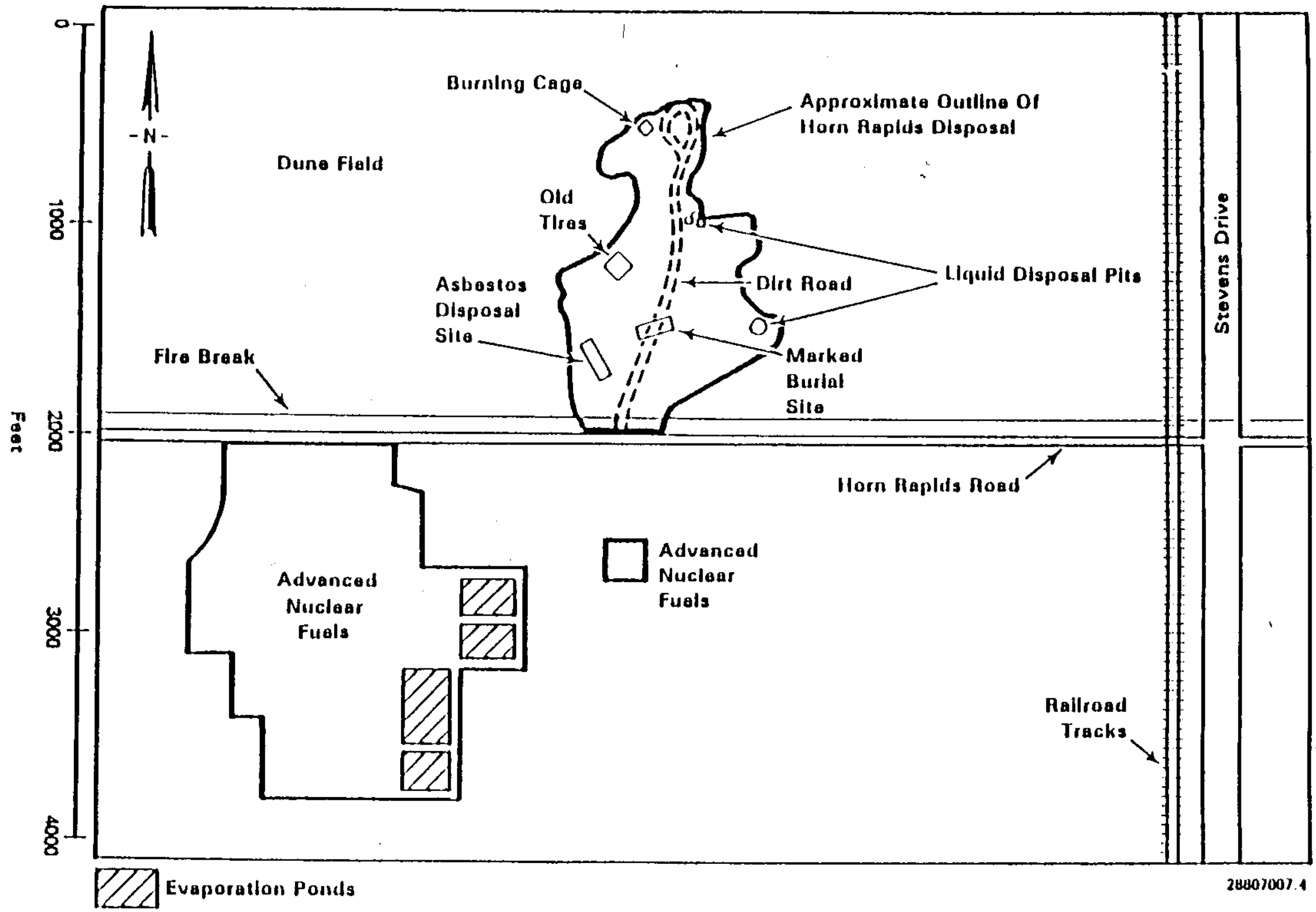

FIGURE 4. Location and approximate outline of the Horn Rapids Landfill.

APPENDIX

Procedures for Geophysical Site Surveys
1100-EM-1 Operable Unit

PROCEDURES FOR GEOPHYSICAL SITE SURVEYS
1100-EM-1 OPERABLE UNIT

G.A. Sandness
Automation and Measurement Sciences Department
Pacific Northwest Laboratory
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1.0 INTRODUCTION

Geophysical sensing methods measure variations in magnetic and electromagnetic fields, electrical currents and potentials, or acoustic impulses to detect and characterize natural or manmade features, objects, or materials in the ground. Some of the many available geophysical exploration methods have proven to be effective at the shallow depths (10 m or less) represented by typical, near-surface, chemical and radioactive waste burial sites. These methods are routinely used to detect waste materials or the subsurface structures (trenches, tanks, drums, etc.) in which those materials were deposited. They are also used to detect natural features (e.g., bedrock, the water table, voids, and sedimentary interfaces) which may influence the migration of chemical or radiological contaminants into the environment. The specific geophysical sensing methods to be initially employed in the planned CERCLA remedial investigations at the Hanford 1100-EM-1 Operable Unit are summarized as follows:

Method	Basic Physical Principle
Ground-penetrating radar	Electromagnetic waves are backscattered from objects or interfaces in the ground.
Magnetometry	Magnetic materials produce measurable anomalies in the ambient (earth's) magnetic field.
Electrical conductivity by electromagnetic induction	Measurable secondary magnetic fields are induced in conductive objects by an alternating magnetic field source at or above the ground surface.
Metal detector	Electromagnetic induction as above with a sensor specialized to detect metallic objects.

These methods, and others, have been successfully used to detect and characterize hazardous waste materials at many burial sites over the past decade and are now recognized as a vital part of waste site identification and assessment efforts. All of these methods provide information about buried objects and materials without requiring significant physical penetration of the ground. For this reason, they offer at least three important advantages, or benefits, in comparison with alternatives such as excavation and borehole sampling: 1) they can substantially reduce the time and cost of exploration and site characterization efforts, 2) they can increase the quality and quantity of site assessment data, and 3) they can enhance the safety of personnel.

These benefits make the use of geophysical sensing methods almost mandatory in most waste burial site investigations.

2.0 GENERAL GEOPHYSICAL SURVEY PROCEDURES

The following sections of this document outline a set of operating procedures for each of the four geophysical survey methods listed above. These procedures include instrument calibration and maintenance, data collection, and data processing. Thus, they are dependent on the characteristics of the various instruments. There are, however, several broader aspects of survey procedure which pertain to all of the methods that we expect to employ in the site investigations that are currently planned for the 1100-EM-1 Operable Unit.

2.1 MEASUREMENT LOCATIONS

Reference points at the ground surface are needed at most waste burial sites to permit measurement locations to be defined and waste boundaries to be accurately mapped. This is often achieved by placing stakes into the ground to mark the nodes of a rectangular grid. Geophysical measurements are then normally made along straight lines that are parallel to, and sometimes coincident with, the grid lines. The reference grids for the sites in the 1100-EM-1 Operable Unit are described in the corresponding RI/FS Work Plan and in the Statement of Work for the geophysical surveys (Work Order No. ED9304). Stakes will be in place at these sites prior to the initiation of geophysical field work.

There are at least two reasons why the geophysical survey, or traverse, lines are not always coincident with the grid lines. First, it may be considered appropriate to collect geophysical data along survey lines that are more closely spaced than the grid lines. It would not be unusual, for example, to collect data along lines spaced 5 or 10 ft apart at a site where the grid (or stake) spacing is 100 ft. The locations of the survey lines, in this case, would be determined by measurements from the grid stakes and would be marked by paint, flags, or other easily movable markers. Second, the stakes are obstructions which make it impossible to maneuver survey vehicles and certain geophysical instruments directly along the grid lines. The normal procedure in this case is to collect data along a set of lines that are offset from the grid lines. The amount of offset and its direction relative to the grid are noted in a field notebook and are accounted for in the subsequent data analysis process.

It is important to note that other obstructions on the ground surface (e.g., bushes, rocks, surface debris, pipes, fences, posts, buildings, and fixed machinery) will often make it impossible to collect geophysical data along perfectly straight lines. A major interruption or diversion of a survey line would be noted and accounted for, but it is impractical to note minor diversions that are comparable to the lateral spatial resolution of the survey instrument or small in comparison to the size of the subsurface feature to be detected (detecting a large trench requires less navigational precision than detecting an isolated 55-gal drum, for example).

Most of the geophysical survey instruments that are planned for use at the Hanford waste burial sites produce output data at an effective rate of several samples per second. The normal survey mode is to transport these instruments along a survey line at a speed of a few feet per second. Thus, the along-track data spacing is typically 1 ft or less. The exact data spacing will vary with the speed at which the instruments are carried or pulled across the ground and cannot be accurately controlled. Except for situations where widely spaced data are appropriate (e.g., electromagnetic induction measurements of deep contamination plumes in groundwater), it is not cost effective to attempt to obtain a fixed data spacing. The normal procedure is to: 1) make the traverse speed as constant as possible to minimize variations in the data spacing; 2) interpolate the data (if digital) by means of a computer to adjust the data spacing to a selected value; and 3) to scale the final display product (e.g., map) to the desired dimensions. This approach minimizes the time needed to perform a survey, maximizes the cost effectiveness of the work, and ensures that the number of measurements in the along-track direction will be sufficient to detect both large and small targets.

2.2 CALIBRATION/DATA ANALYSIS

The current state of the art in geophysical site assessment technology is such that the results of most surveys are only semi-quantitative. In other words, the amplitude of a measured quantity (e.g., a reflected radar signal, a magnetic field anomaly, or the apparent electrical conductivity of the ground) cannot be interpreted in a way that will yield an accurate quantitative characterization of a buried waste deposit or waste-related structure. Consequently, the most meaningful and accurate result of a geophysical survey is usually a map showing the locations of waste deposits or waste disposal structures. This type of product is based on the measurement of lateral variations in the measured quantity. Thus, the stability of the survey instrument and the accuracy of the survey lines are more important than a calibration of the instrument's response. The instrument calibrations that can be made and are meaningful are outlined in Sections 3-6.

2.3 SAFETY

There are minimal safety hazards associated with the use of the geophysical survey instruments that are planned for use at the Hanford Site. The instruments themselves have no significant radiation fields, exposed high voltages, or moving mechanical parts that constitute a hazard to the operator. The small all-terrain vehicle used by PNL for ground-penetrating radar surveys (see Section 3.1 below) will not be operated on steep slopes or embankments which, in the judgement of the operator, cannot be safely negotiated. Safety issues related to potential chemical or radioactive contamination of the site and to the possibility of ground subsidence over collapsing waste materials or containers will be addressed by the site safety officer prior to the initiation of geophysical field work by PNL.

2.4 FIELD NOTEBOOKS

Written descriptions of the geophysical field work will be recorded in field notebooks. The contents of these notebooks will include site descriptions, explanations of the work being performed, general field procedures, a list of the instruments used in the work, records of instrument settings, notations of anomalous occurrences, and descriptive details relating to data collection (e.g., line numbers, traverse directions, obstructions, deviations, data record numbers, and data file names). A separate notebook will be used by each individual or group that is performing independent field work. The notebooks will remain at PNL, but copies will be provided to WHC.

2.5 REPORTS

Final reports will be submitted to WHC as outlined in the Statement of Work for the 1100-EM-1 Operable Unit. These reports will include:

- site description
- statement of survey objectives
- listing and description of the survey instrumentation
- outline of data collection procedures
- outline of data processing operations and data analysis procedures
- discussion of results
- raw data records
- intermediate data display products (maps, profiles, and graphs)
- one or more site maps showing the interpreted results of the geophysical surveys.

3.0 GROUND-PENETRATING RADAR PROCEDURES

3.1 SYSTEM

Manufacturer	Geophysical Survey Systems, Inc (GSSI)
Components	a) Control unit, Model SIR 7 b) 120-MHz antenna, Model 3110 c) 300-MHz antenna, Model 3105A d) 500-MHz antenna, Model 3102 e) Calibrator, Model P731 Normal operation of the radar system involves two additional components: f) Digital data acquisition unit designed and constructed at PNL. g) Suzuki Quadrunner 250 all-terrain vehicle (ATV).

Power	Electrical power is provided by 12-volt automotive or marine batteries.
Accuracy	±0.5 nsec in signal travel time.

3.2 MANUALS

a) GSSI SIR 7 operator's manual and circuit diagrams.
b) PNL operator's manual, data acquisition unit.

3.3 CALIBRATION

A radar travel-time calibration signal will be recorded in the field as a special data record on the recording medium used for the rest of the radar field data (digital magnetic tape or disk). A calibration, utilizing the P731 calibrator, will be performed at least once per day during field operations and whenever a change is made in the timing parameters of the radar system. The performance of the calibration procedure and the location of the calibration data in the recorded data set will be noted in the operator's field notebook.

3.4 MAINTENANCE

Daily Procedures:

a) Inspection and cleaning (if needed) of cables, connectors, and tape recorder heads.
b) Battery inspection and charging prior to operation of the system. (During operation, battery status is indicated by a voltmeter and indicator lights on the radar control unit.)
c) ATV maintenance (gas, oil, tires).

The performance of these procedures will be noted in the operator's field notebook.

3.5 DATA COLLECTION

Operating Modes

a) Towed by the ATV. In this mode, a footage counter mounted on the ATV provides position data that are inserted into the data records.
b) Pulled by the operator, no footage counter.

The operating mode will be recorded in the operator's field notebook.

Normal travel speed	2-5 ft/sec
Warm-up time	1 minute
Procedures	System adjustments such as time scale, gain, filter, sampling rate, and signal frequency range (antenna selection) are site-dependent and will

be made at the discretion of the operator. All instrument settings will be recorded in the operator's field notebook.

Data will normally be collected along straight lines defined by, or derived from, a survey grid marked by stakes. Pertinent data (e.g., direction, location, track number, obstructions) relating to each traverse will be recorded in the operator's field notebook.

The radar data will be recorded in digital form on magnetic tape cartridges or magnetic disks. Each cartridge or disk will be labeled and dated. The data will be transferred to a laboratory computer for processing as described below. The unprocessed data will be recorded on 9-track magnetic tape for long-term storage and transmittal to WHC.

3.6 DATA ANALYSIS

The radar data will be processed by PC or DEC VAX computers. Processing steps may include clutter removal, filtering, synthetic aperture focusing, and image enhancement. Intermediate output products will normally be amplitude-modulated radar profiles in the form of photographic prints. The final product will normally be a site map showing the interpreted locations, depths, and characteristics of waste materials and other waste-related features. This map may include the results of the other types of geophysical surveys performed at the site.

4.0 MAGNETOMETER PROCEDURES

4.1 PRIMARY SYSTEM

Manufacturer	Scintrex, Ltd.
Components	a) Cesium vapor magnetometer, Model VIW-2302A1 b) Digital data recorder designed and constructed at PNL.
Power	6-volt gel-cell battery pack
Accuracy	± 5 gammas

4.2 ALTERNATIVE SYSTEM

Manufacturer	Geometrics
Components	Proton precession magnetometer, Model G-816 or G-856.
Power	Internal batteries (size C, non-magnetic)
Accuracy	± 1 gamma

4.3 MANUALS

a) Scintrex magnetometer operator's manual and circuit diagrams.
b) PNL operator's manual, digital data recorder.
c) Geometrics magnetometer operator's manual.

4.4 CALIBRATION

The calibration of cesium vapor and proton precession magnetometers is determined by fundamental physical constants and is not adjustable by the user. A correct reading of the ambient magnetic field indicates that the instrument is functioning correctly. Short-term stability will be ascertained daily by a 1-minute sequence of measurements at a fixed field location. Long-term repeatability will be checked by repeating at least one survey line at each site. The performance of these steps will be documented in the operator's field notebook.

4.5 MAINTENANCE

Daily battery charging and inspection of cables and connectors. During operation, low battery voltage is sensed by the magnetometer and is indicated on its front panel display.

4.6 DATA COLLECTION

Operating mode	The instrument will be carried by the operator.
Normal travel speed	a) 3-5 ft/sec (cesium vapor magnetometer). b) 1 ft/sec avg. (proton precession magnetometer).
Warm-up time	a) 5 minutes (cesium vapor magnetometer). b) 1 minute (proton precession magnetometer).
Procedures	Before beginning a survey, the operator will ensure that he is not carrying or wearing any ferromagnetic object (e.g., knife, steel belt buckle, or steel-reinforced boots) that can affect the magnetic measurement.

The cesium vapor magnetometer will be carried along the survey lines at a constant speed. Data will be automatically recorded in digital form at a rate of several samples per second.

The proton precession magnetometer will be moved along the survey lines in a start/stop mode. Readings will be made at selected distance increments and will be recorded either automatically (recorder) or manually (notebook).

Data stored in the digital data recorder will be periodically transferred to floppy disk via an on-site PC. Each floppy disk will be labeled, dated, and backed up. Pertinent data relating to each survey line will be recorded in the operator's field notebook.

Diurnal variations in the earth's magnetic field will be monitored by making periodic measurements at a fixed location. The measurement interval will be 1 hour or less. The details of this procedure will be recorded in the operator's field notebook.

4.7 DATA ANALYSIS

The magnetic data will be processed by a PC or VAX computer. Processing steps may include interpolation, filtering, correction for diurnal variations, and subtraction of the ambient field. Output products may include magnetic profiles, contour maps, and color-coded maps of magnetic amplitudes. The primary output product will normally be a site map showing the interpreted locations of magnetic waste materials. These results may be included on a more general site map that contains the results of other geophysical surveys.

5.0 ELECTROMAGNETIC INDUCTION PROCEDURES

5.1 SYSTEM

Manufacturer	Geonics. Ltd.
Components	a) Model EM31 ground conductivity meter. b) Digital data acquisition unit as in Section 4.1.
Power	Internal batteries, size C
Accuracy	$\pm 5\%$

5.2 <u>MANUALS</u>	Geonics EM31 Operating Manual and circuit diagrams.
5.3 <u>CALIBRATION</u>	Factory calibrated. Long-term stability will be checked prior to use at a given site by measurements at a selected test location (currently a parking lot at PNL's 2400 Stevens facility). Adjustments, if needed, will be made in accordance with the procedures listed in the EM31 Operating Manual. The time, location, procedures, and results of these measurements and adjustments will be recorded in the operator's field notebook.
5.4 <u>MAINTENANCE</u>	Daily procedures: a) Inspection of cables and connectors. b) Equipment functional checks as specified in the operator's manual. The performance of these procedures will be noted in the operator's field notebook.
5.5 <u>DATA COLLECTION</u>	
Operating mode	The instrument will be carried by the operator.
Normal travel speed	3-5 ft/sec
Warm-up time	1 minute
Procedures	The instrument will be carried along the survey lines at a constant speed. Data will be automatically recorded in digital form at a rate of several samples per second. Pertinent data related to each survey line will be recorded in the operator's field notebook. The recorded data will be transferred to floppy disks which will be labeled, dated, and backed up.
5.6 <u>DATA ANALYSIS</u>	The data will be processed by a PC or VAX computer. Processing steps may include interpolation and filtering. Output products may include conductivity (apparent) profiles, contour maps, and color-coded maps. The primary output product will normally be a site map showing the interpreted locations of detected waste materials or subsurface structures. These results may be included on a more general site map that contains the results of other geophysical surveys.

6.0 METAL DETECTOR PROCEDURES

6.1 SYSTEM

Manufacturer	Fisher Research Laboratory
Components	Model TW-6 M-Scope pipe and cable locator
Power	Internal batteries
Accuracy	Not defined

6.2 MANUALS

Fisher M-Scope Operating Manual

6.3 CALIBRATION

Uncalibrated instrument. Frequent adjustments are required on site to ensure good sensitivity. These are normally made by maximizing the response to a known target. This procedure will be recorded in the operator's field notebook.

6.4 MAINTENANCE

Daily battery check utilizing the instrument's front-panel, battery-check function switch.

6.5 DATA COLLECTION

Operating mode	The instrument will be carried by the operator.
Normal travel speed	1-5 ft/sec
Warm-up time	1 minute
Procedures	The instrument will normally be carried along a survey line until a response is obtained. The instrument may then be moved in an areal pattern to define the boundaries of the detected object or material. The boundaries will be marked on the ground in a temporary manner and will be recorded on a data sheet or in the operator's field notebook.

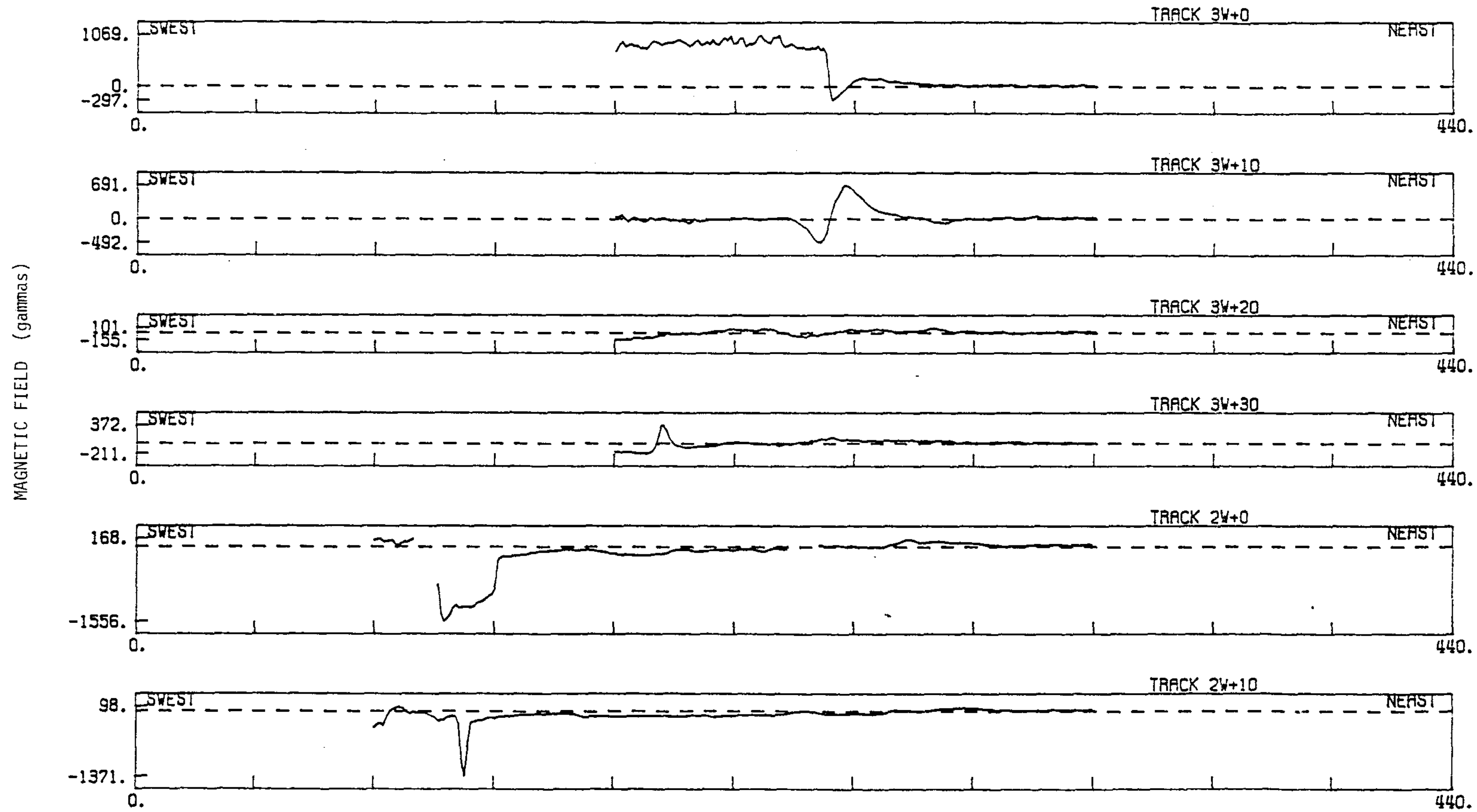
6.6 DATA ANALYSIS

The field records will be replotted and presented either as a separate map or as a component of a more general site map containing the results of other geophysical surveys.

DATA PROFILES

MAGNETIC PROFILES

MAGNETIC PROFILES, SITE 1100-2



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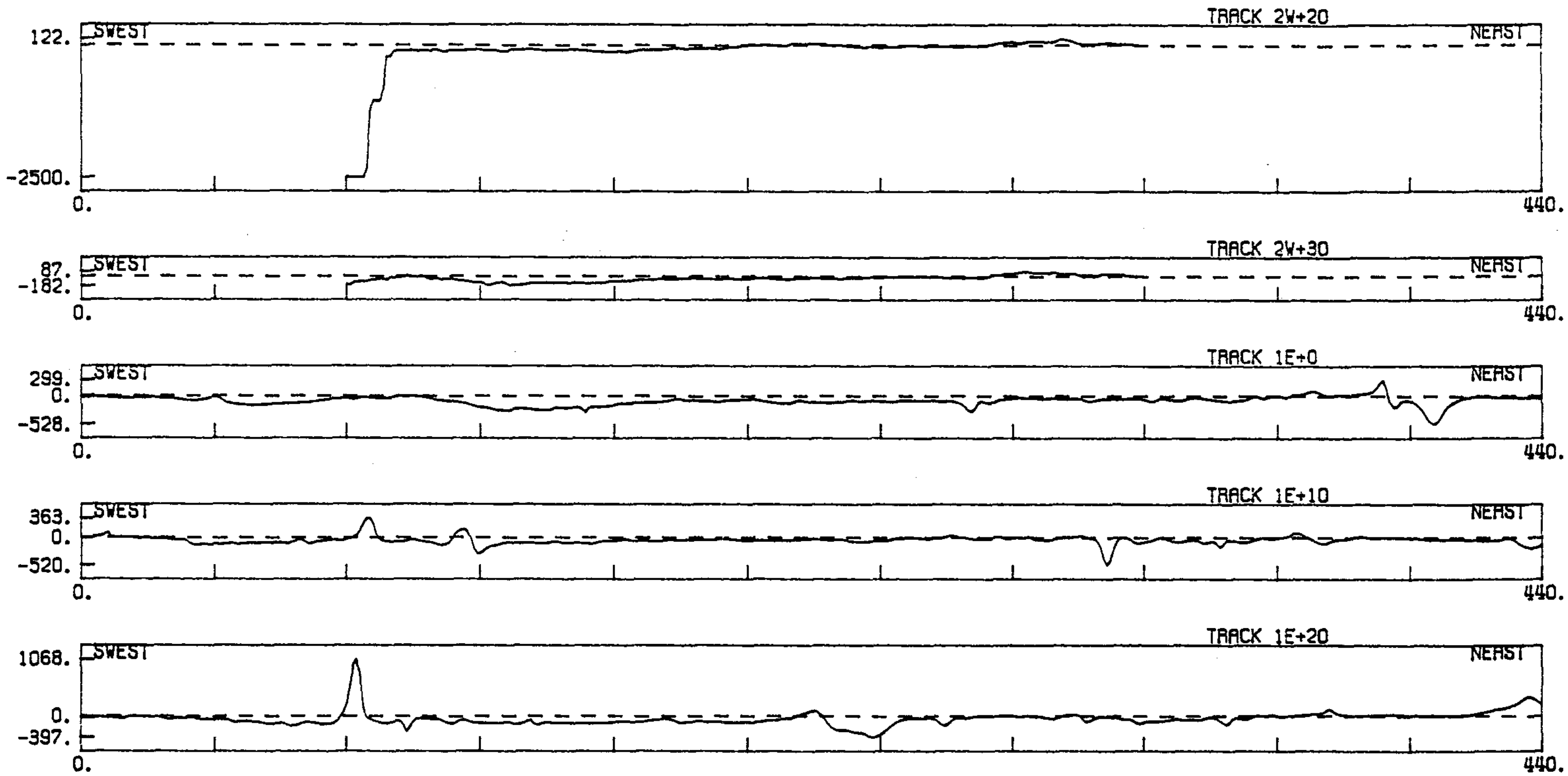

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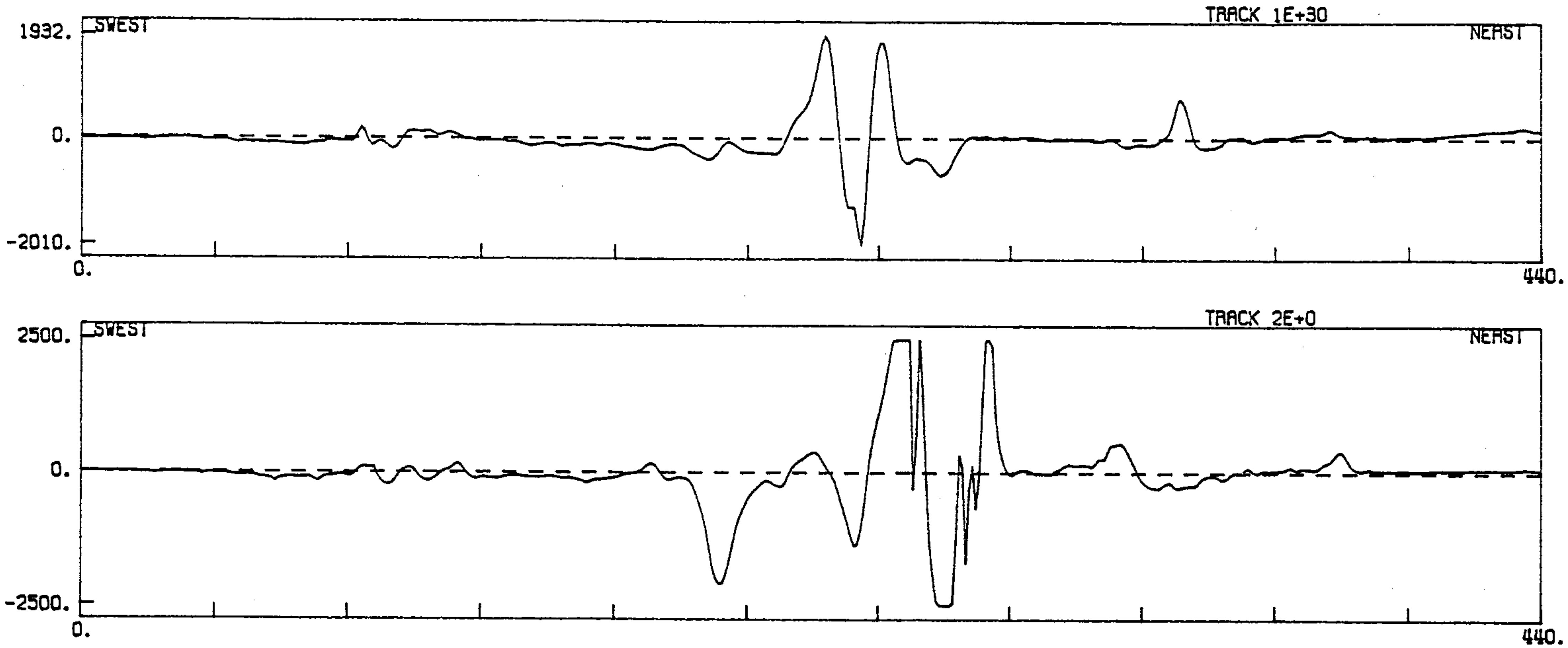

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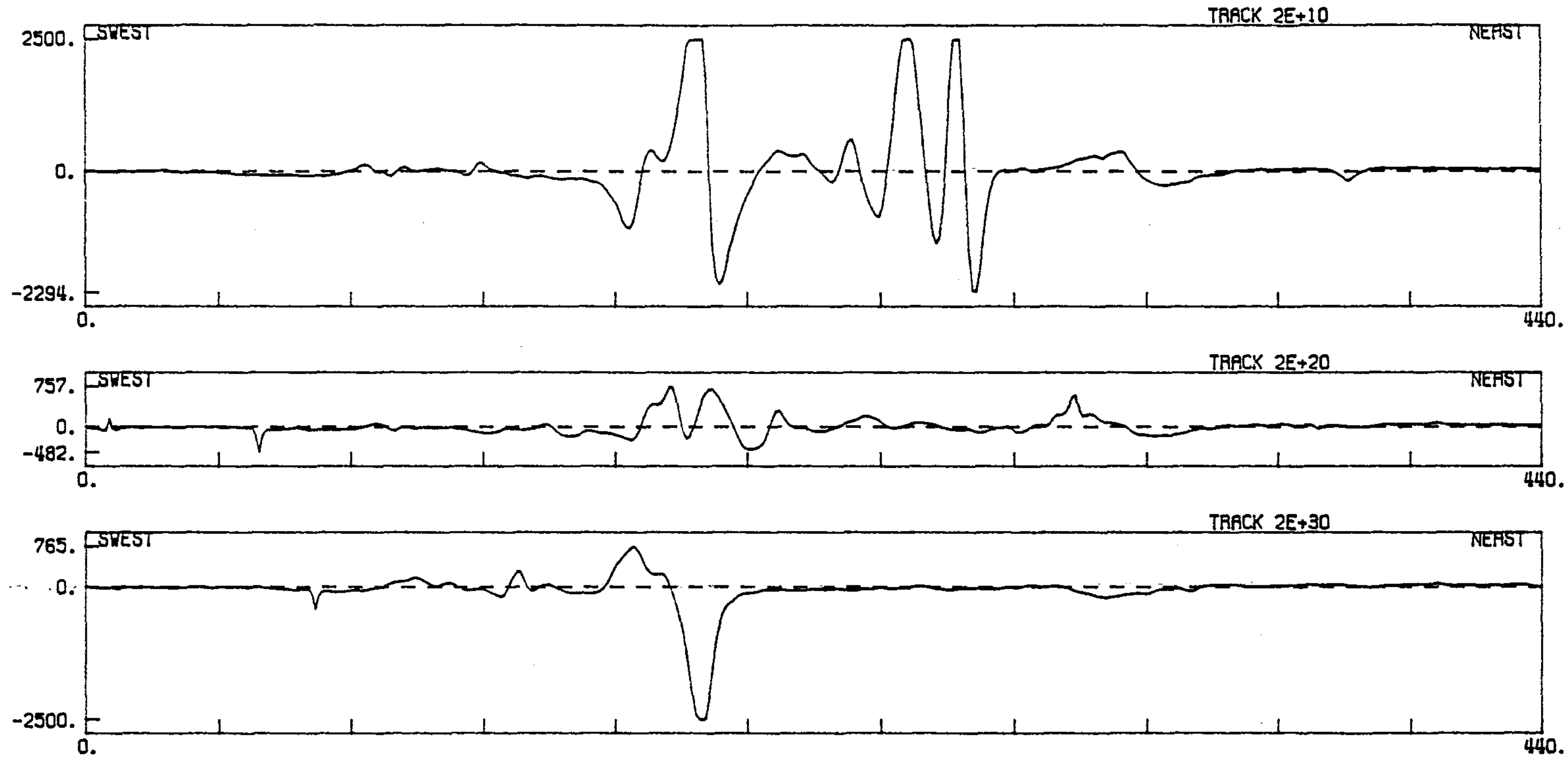

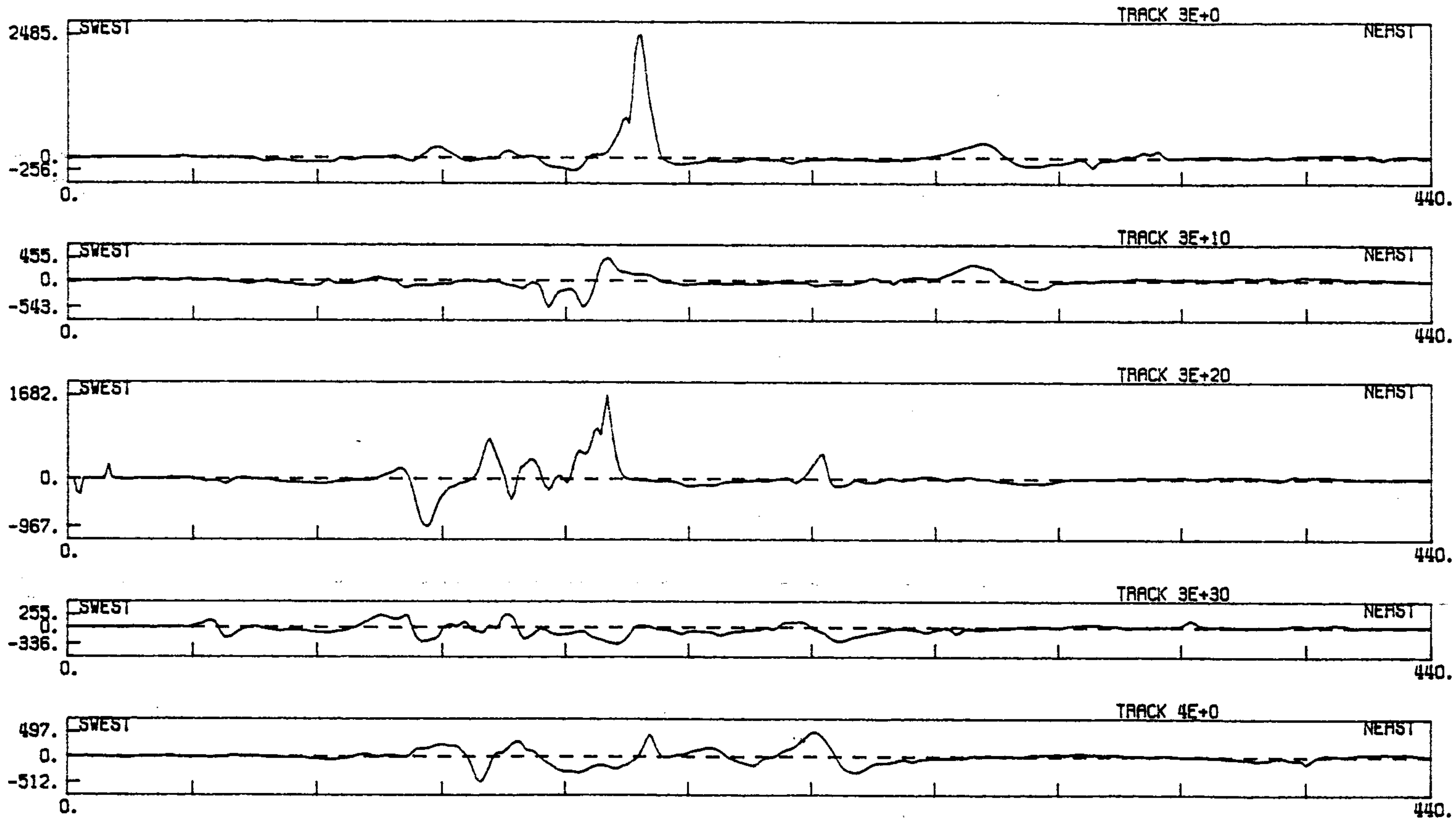
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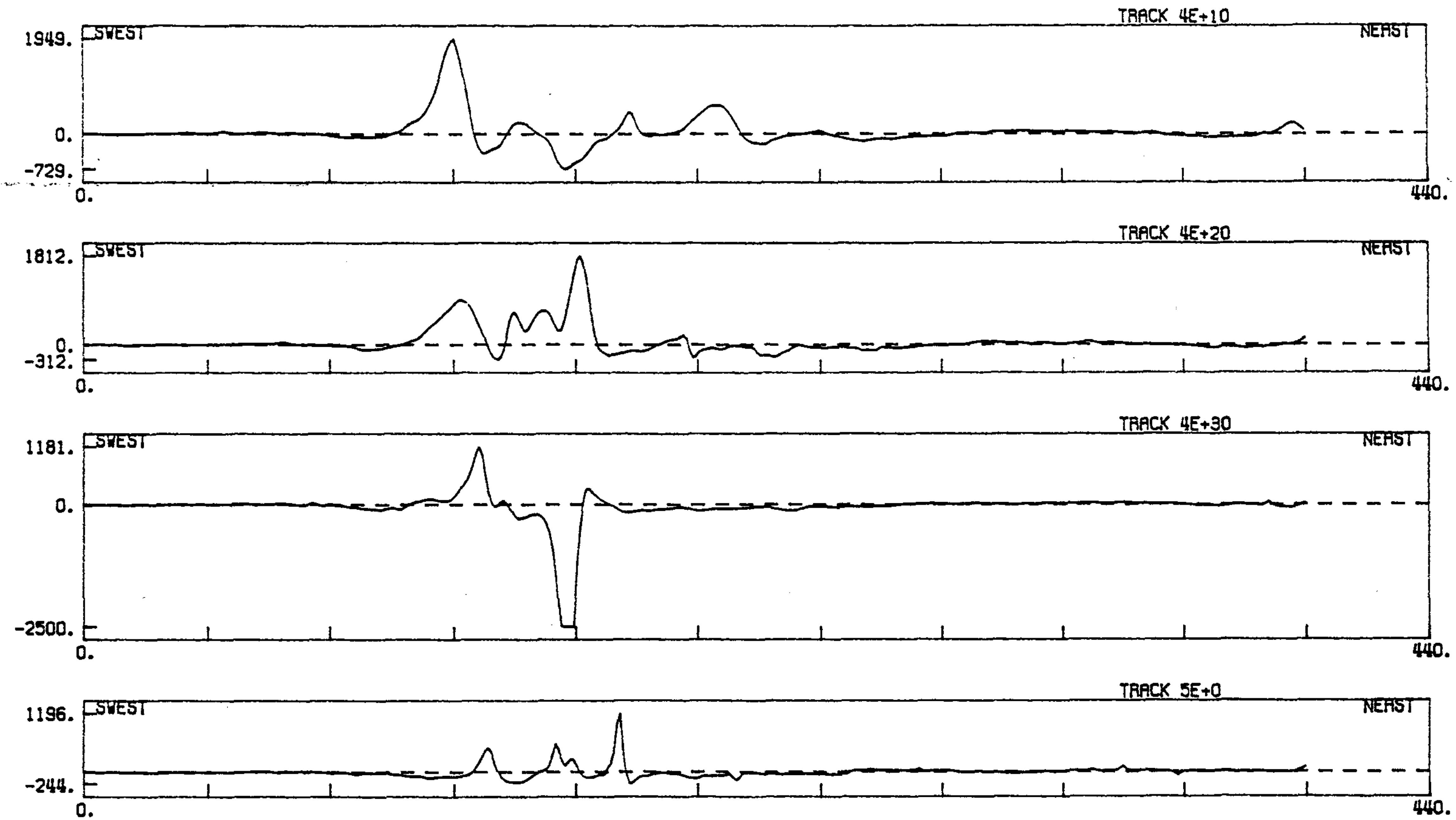
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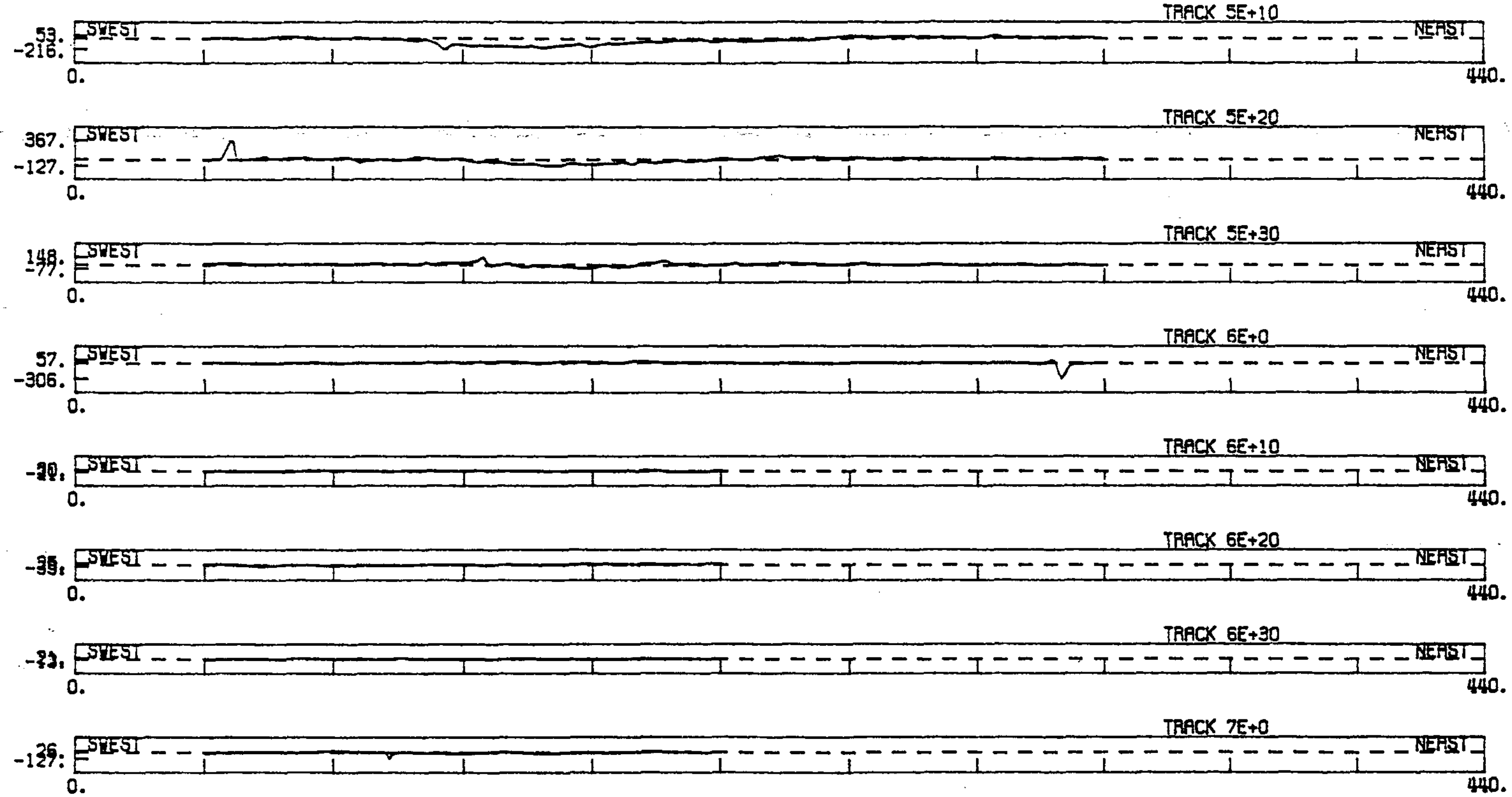
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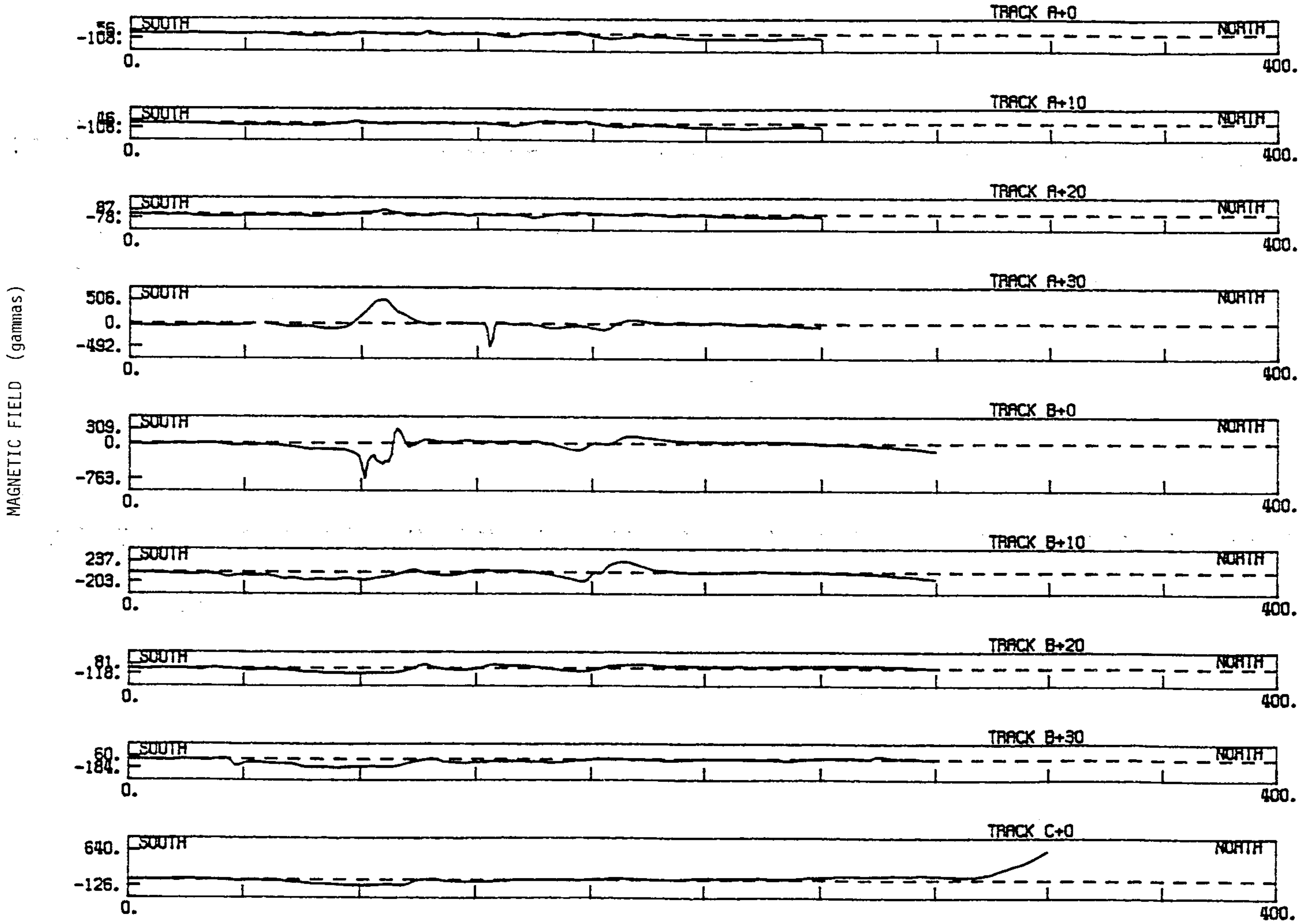

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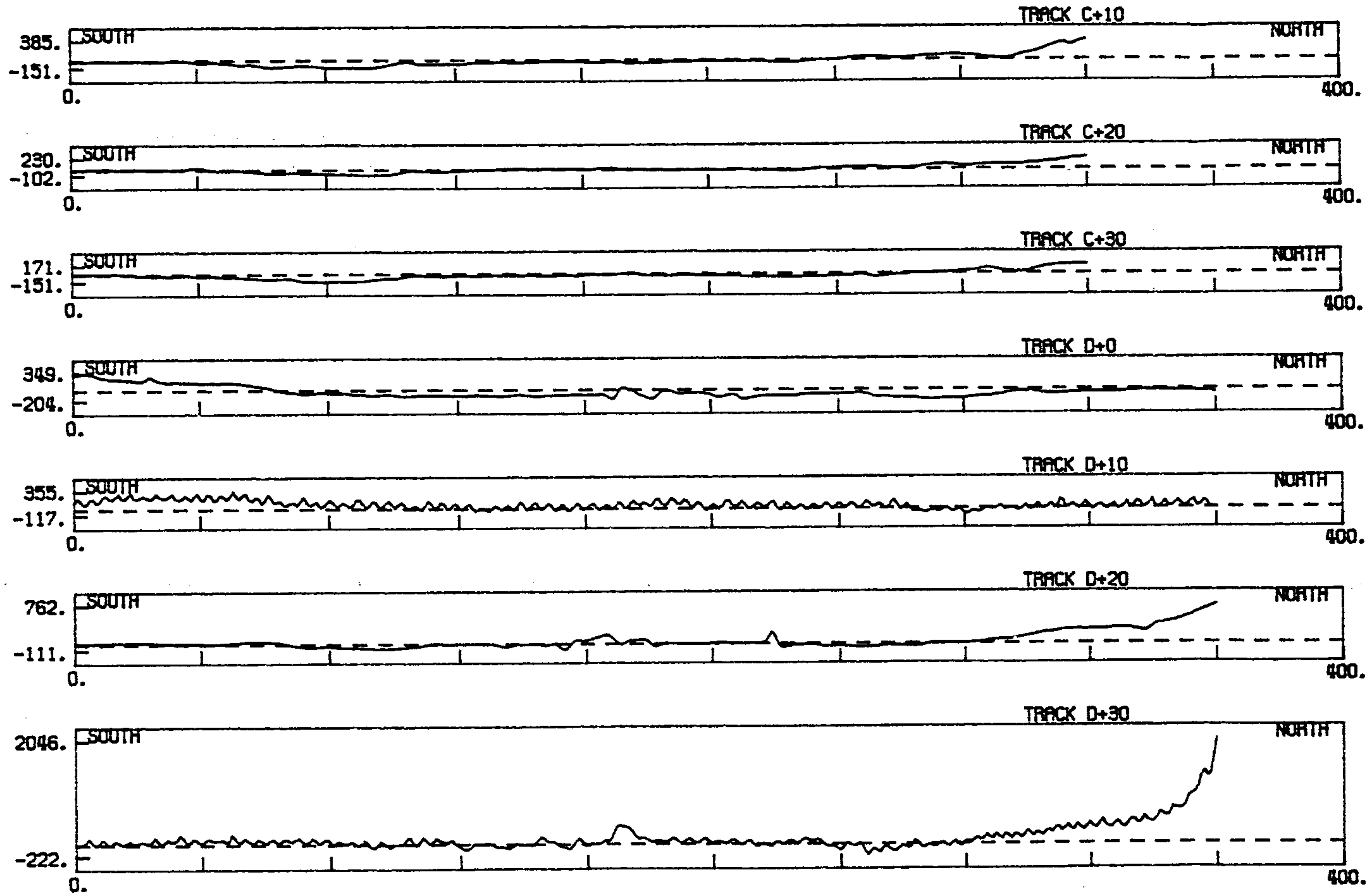

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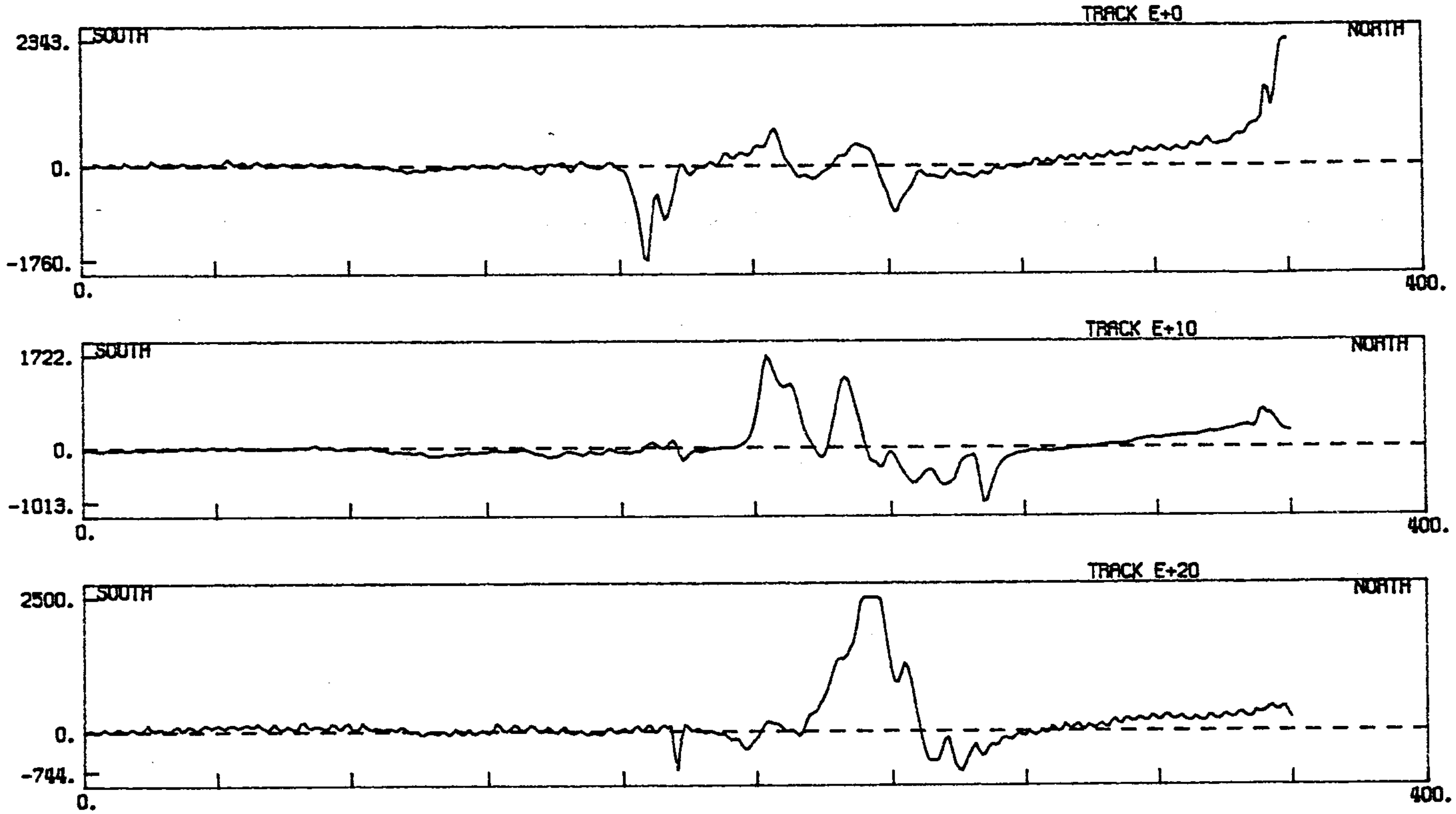

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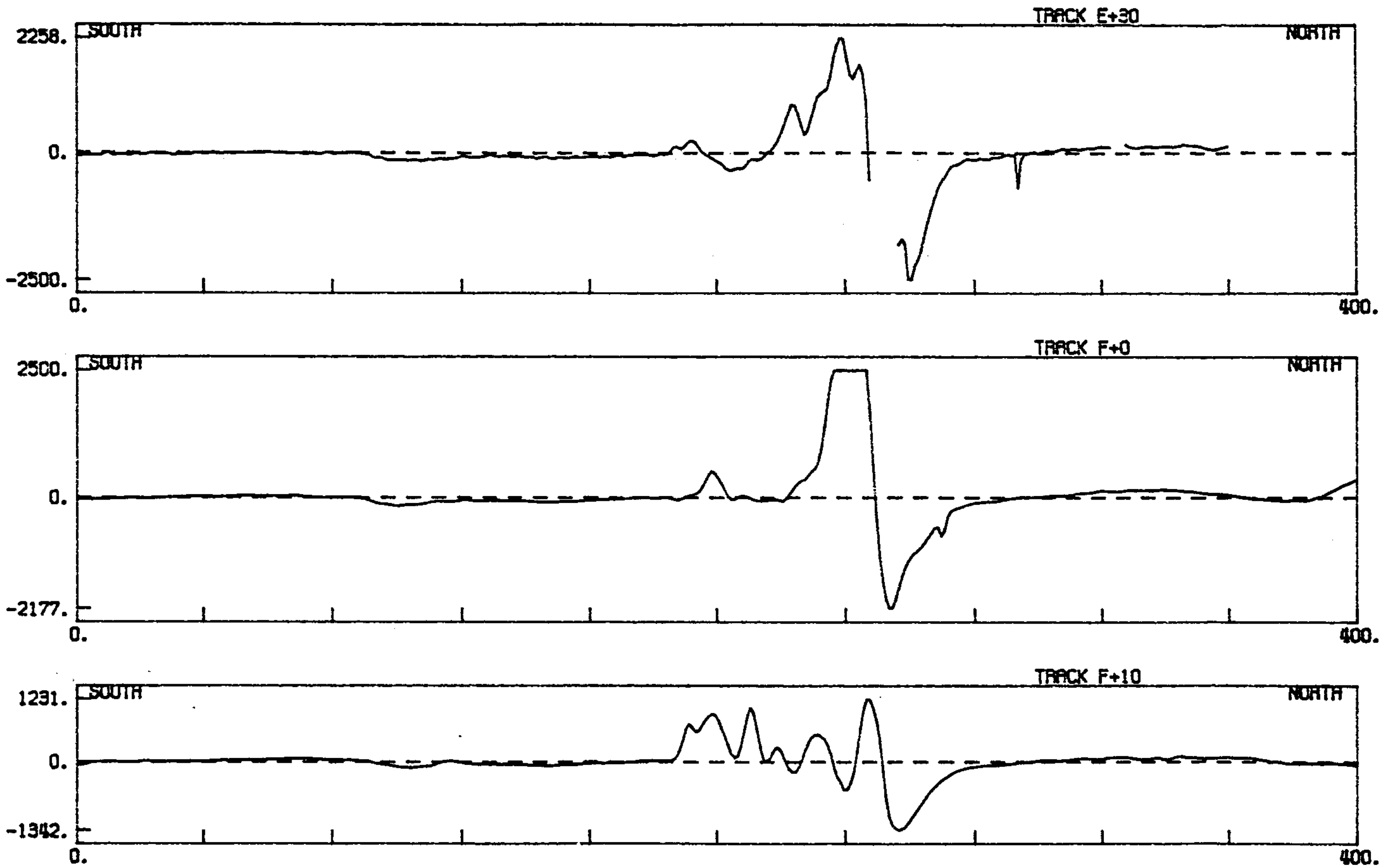

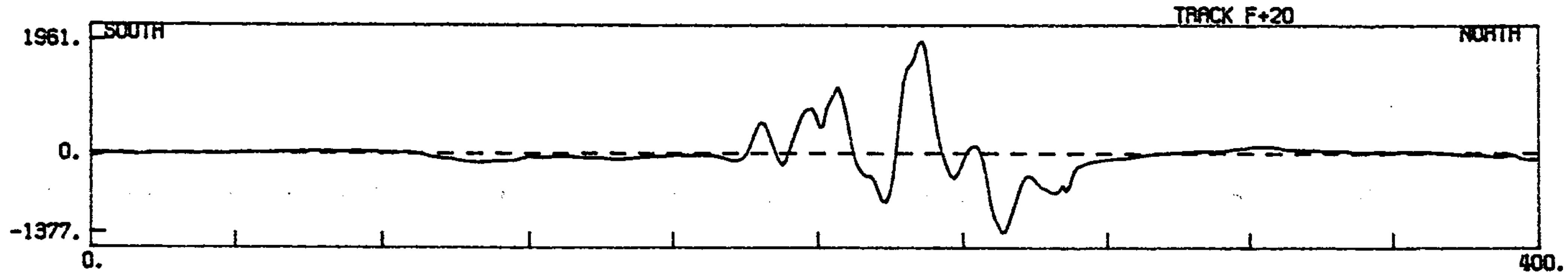
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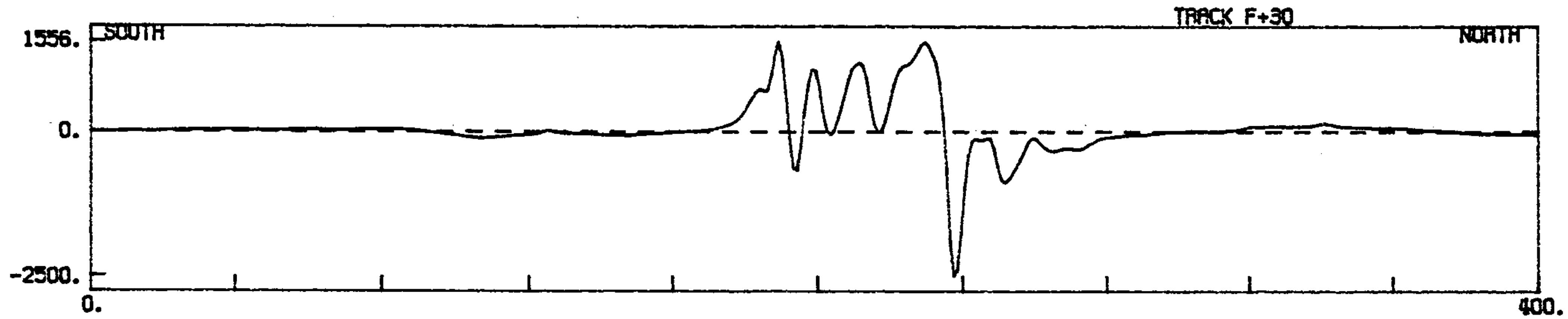
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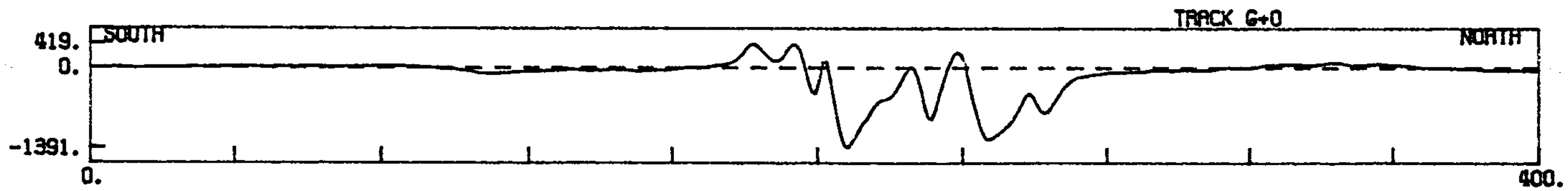
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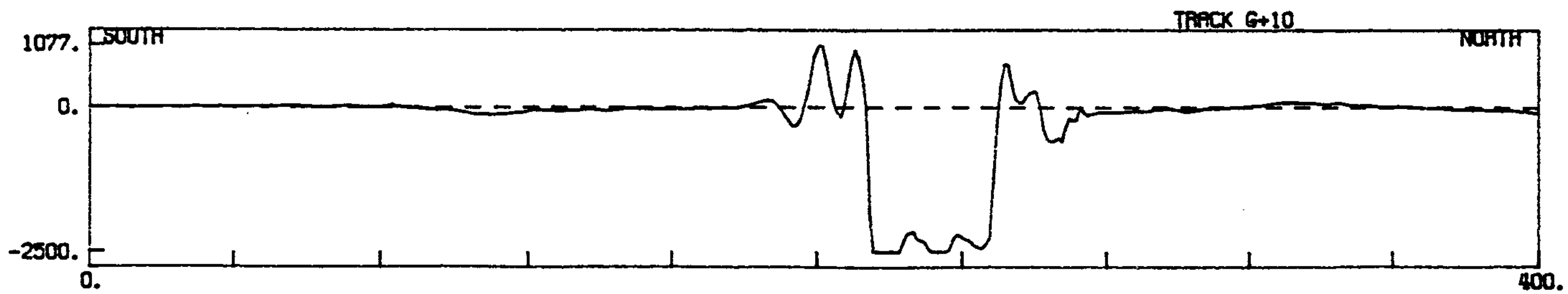
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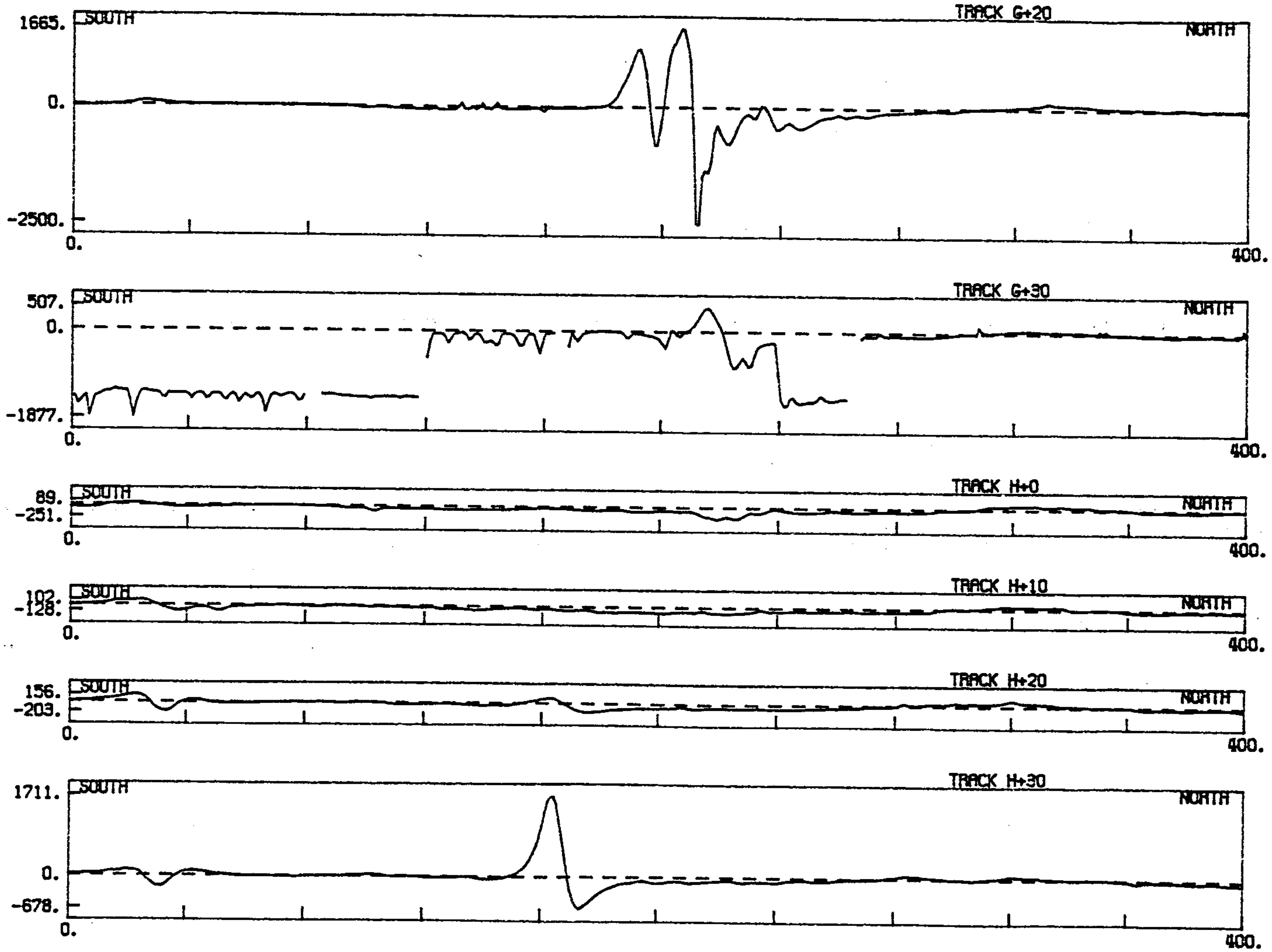
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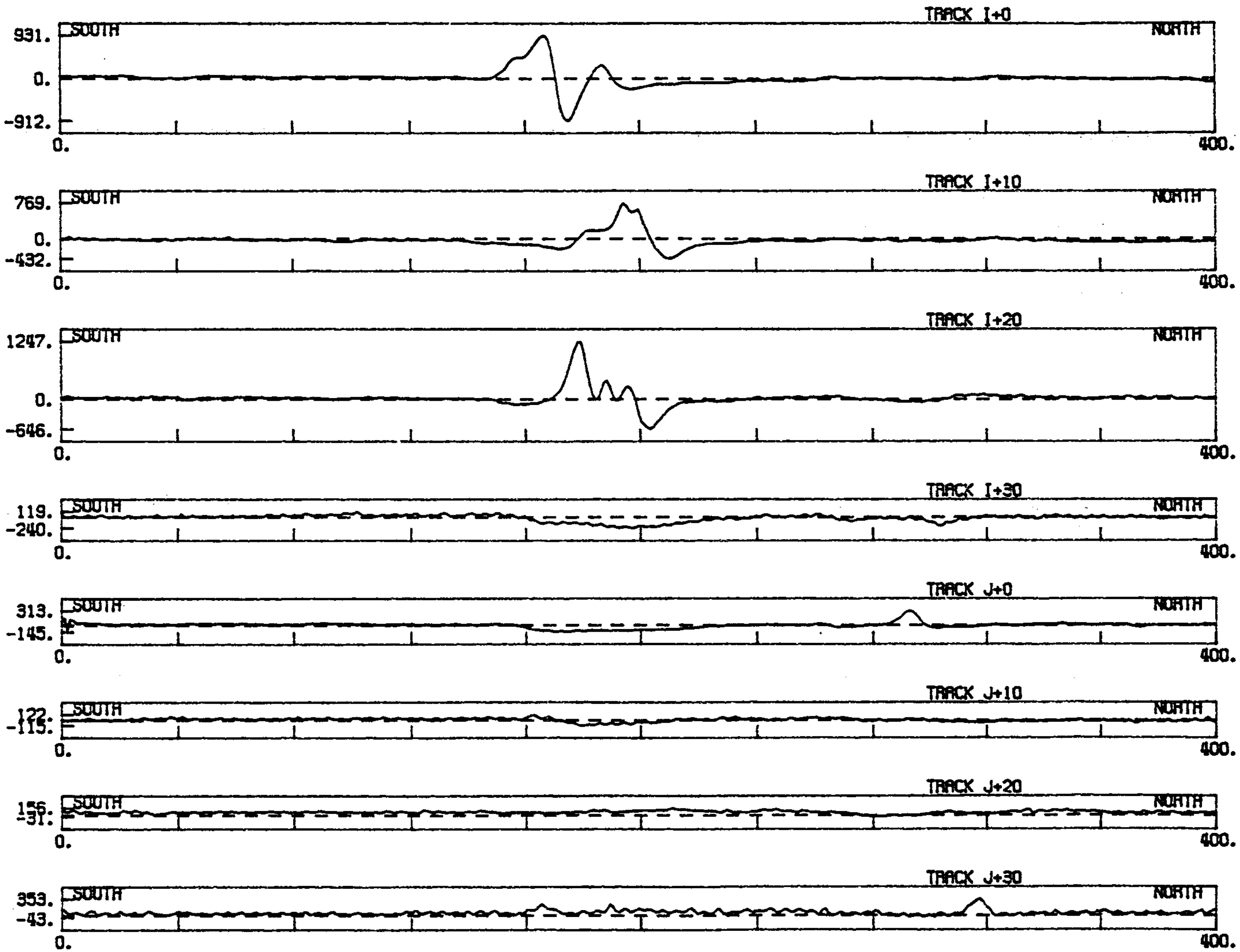
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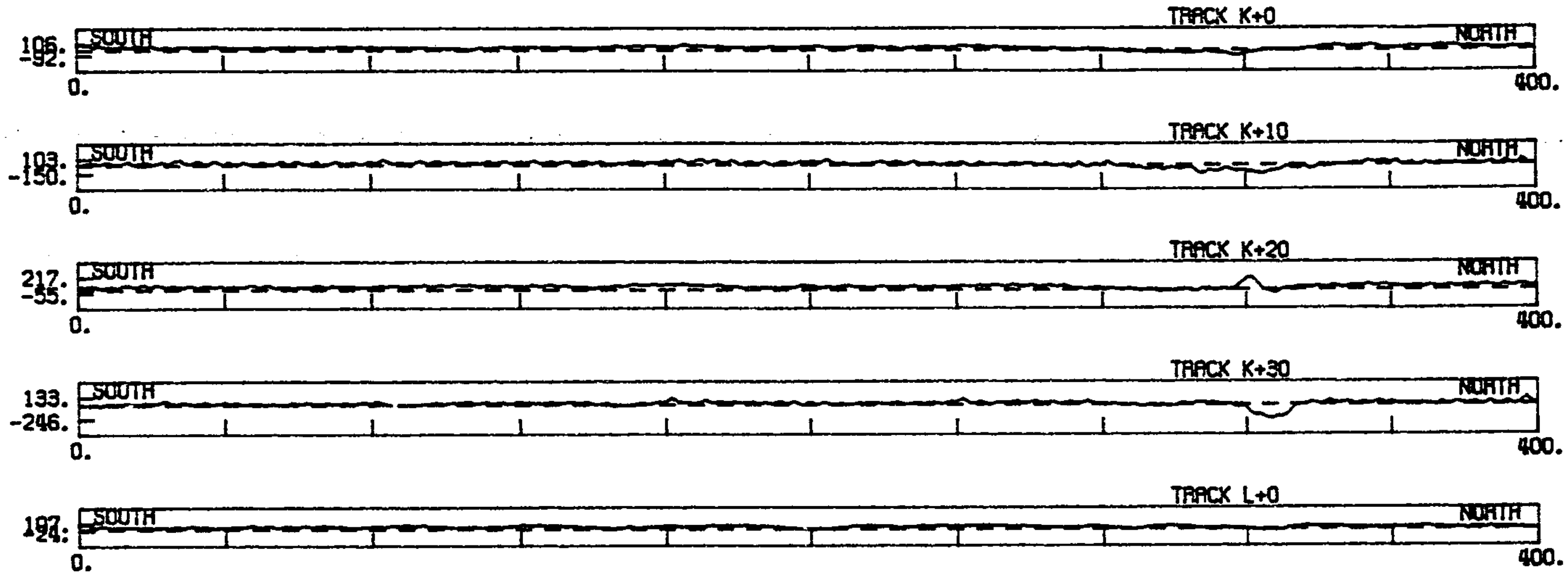
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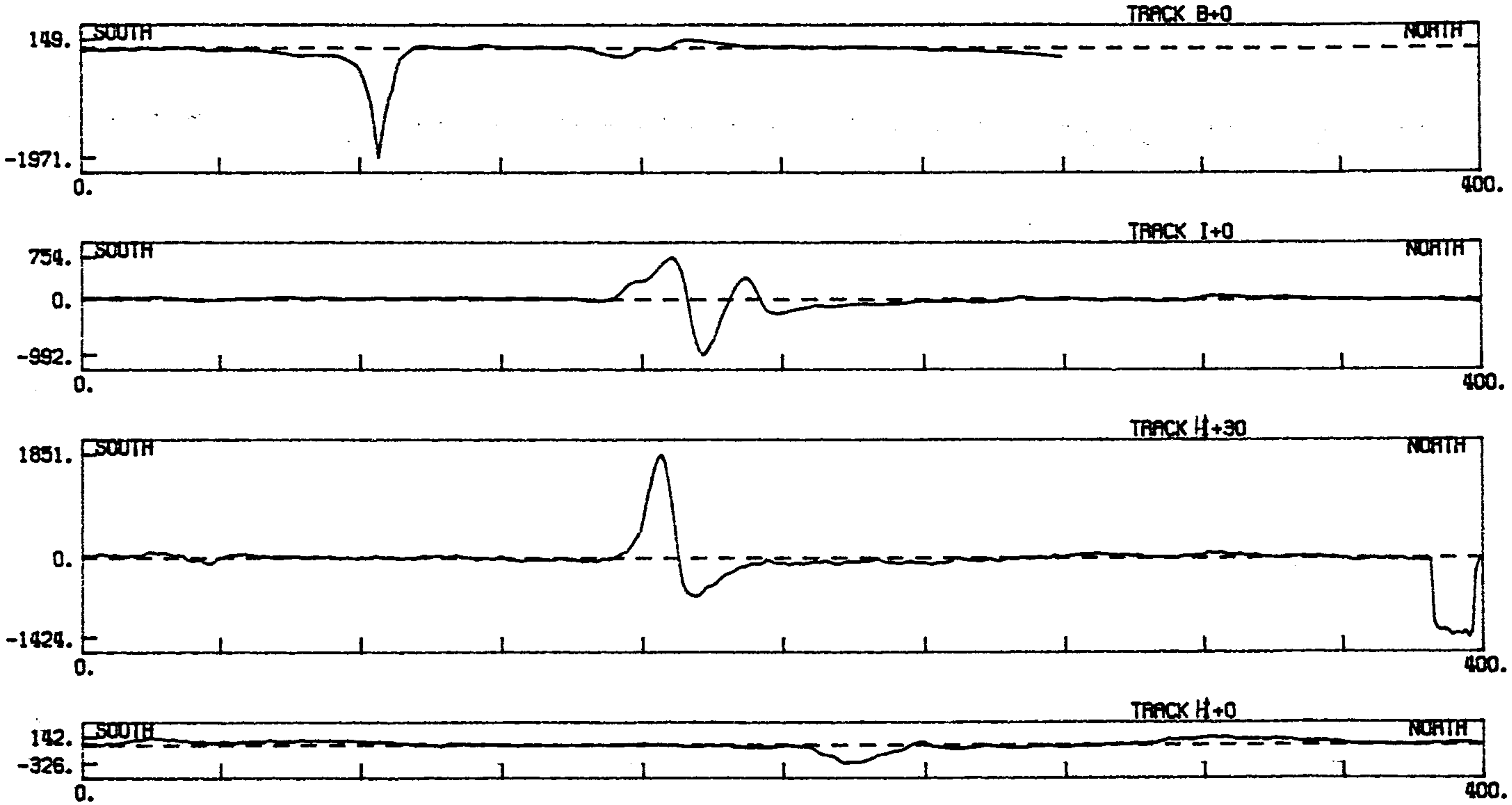
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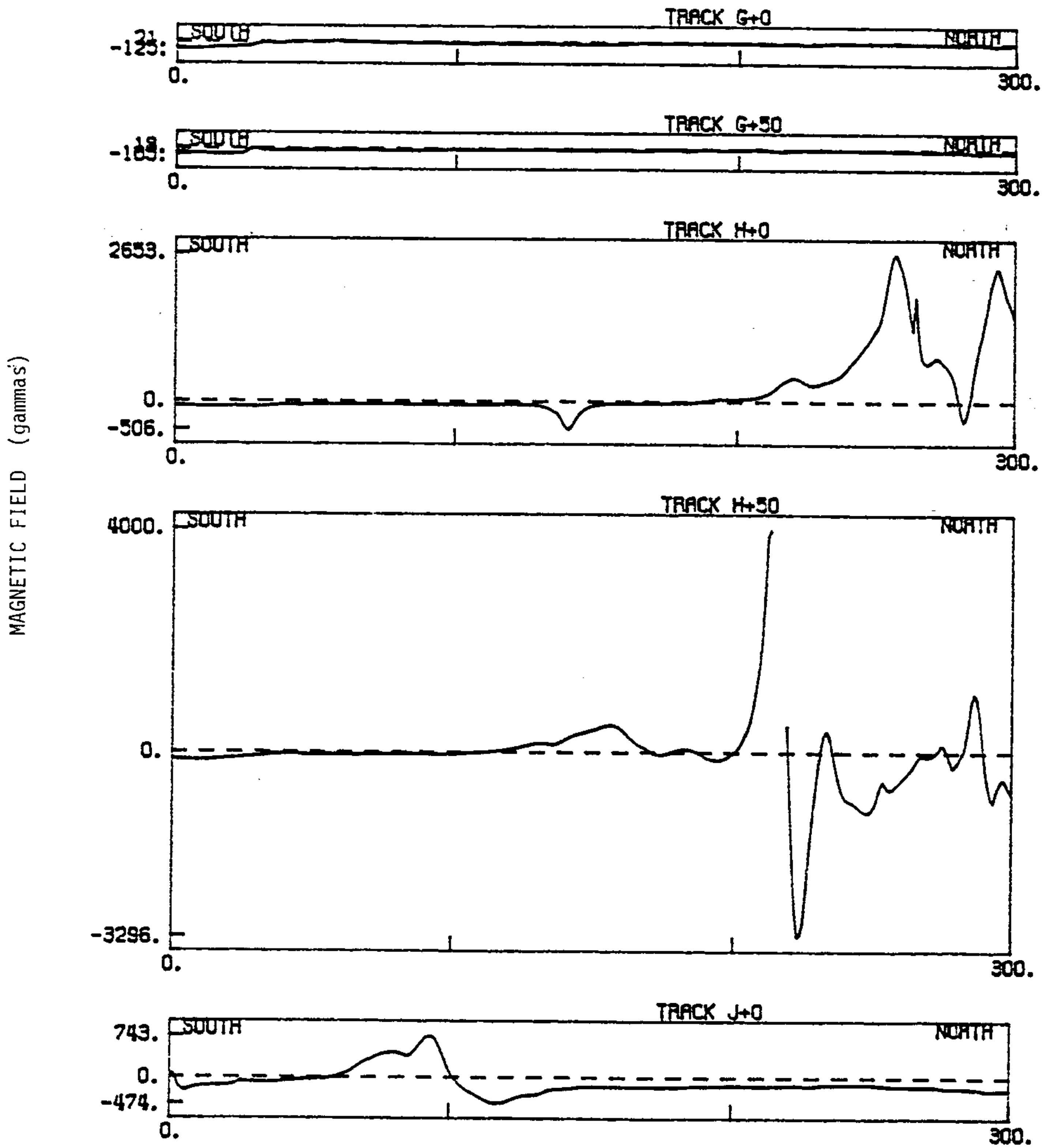
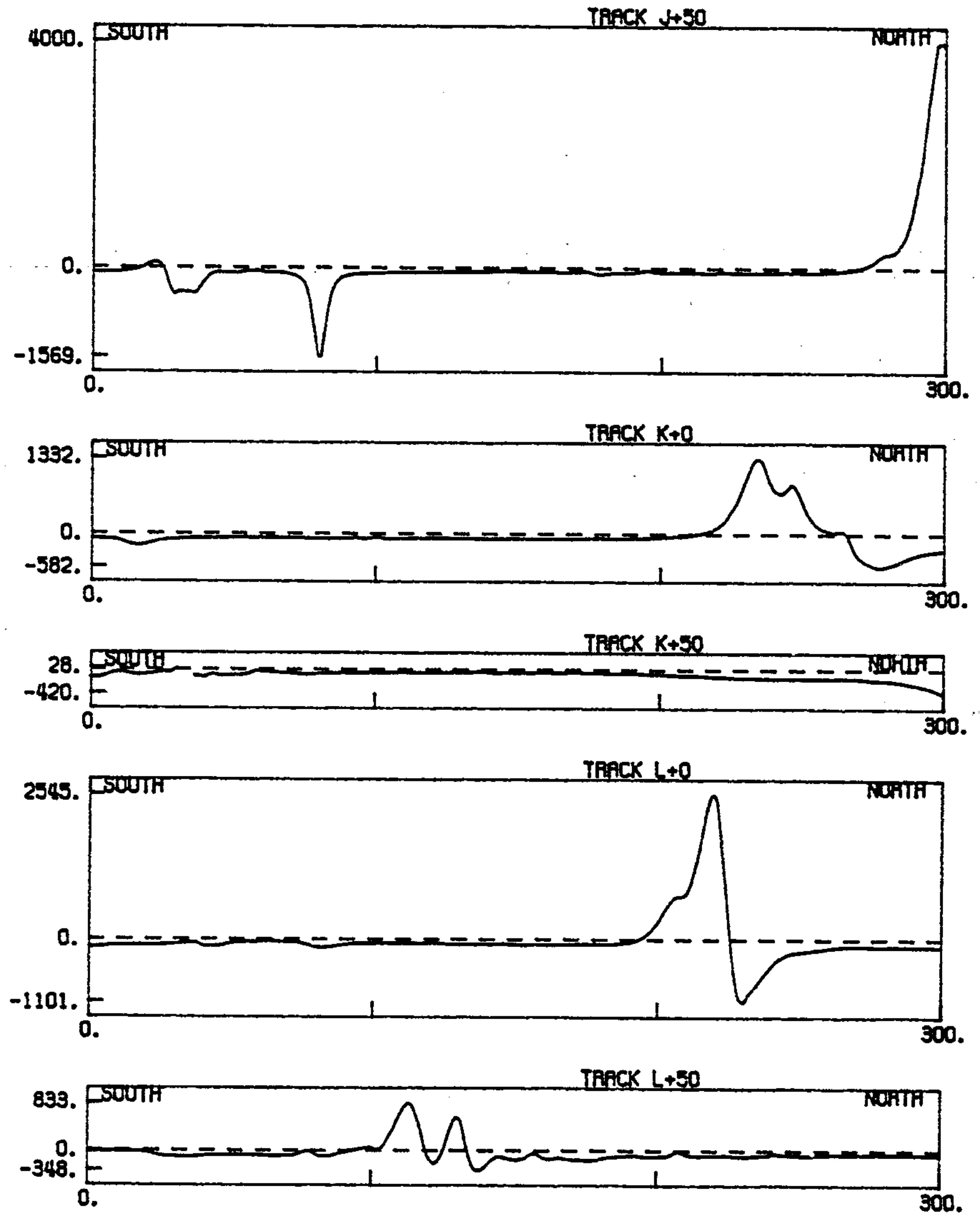
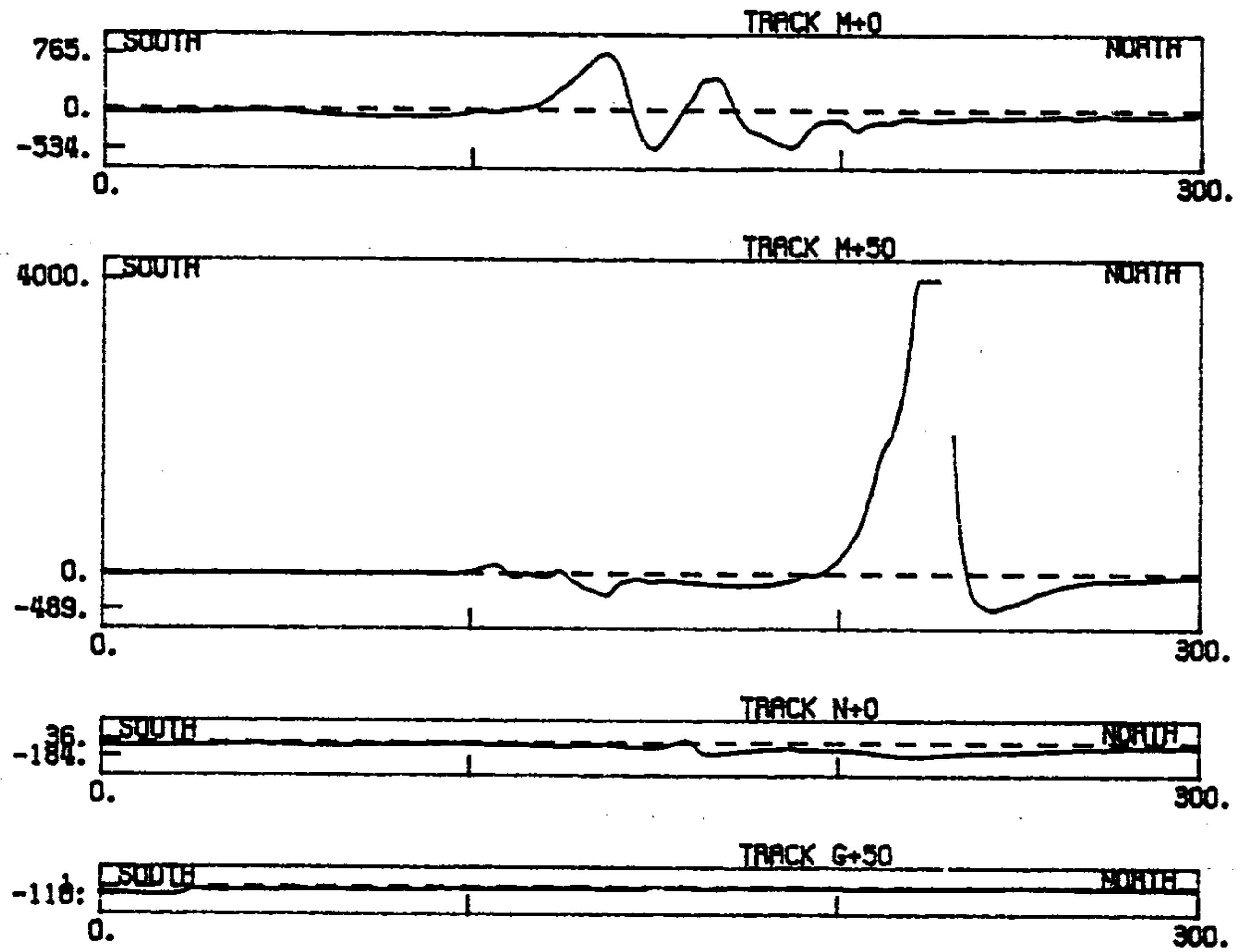
MAGNETIC PROFILES, HORN RAPIDS LANDFILL PAGE 1

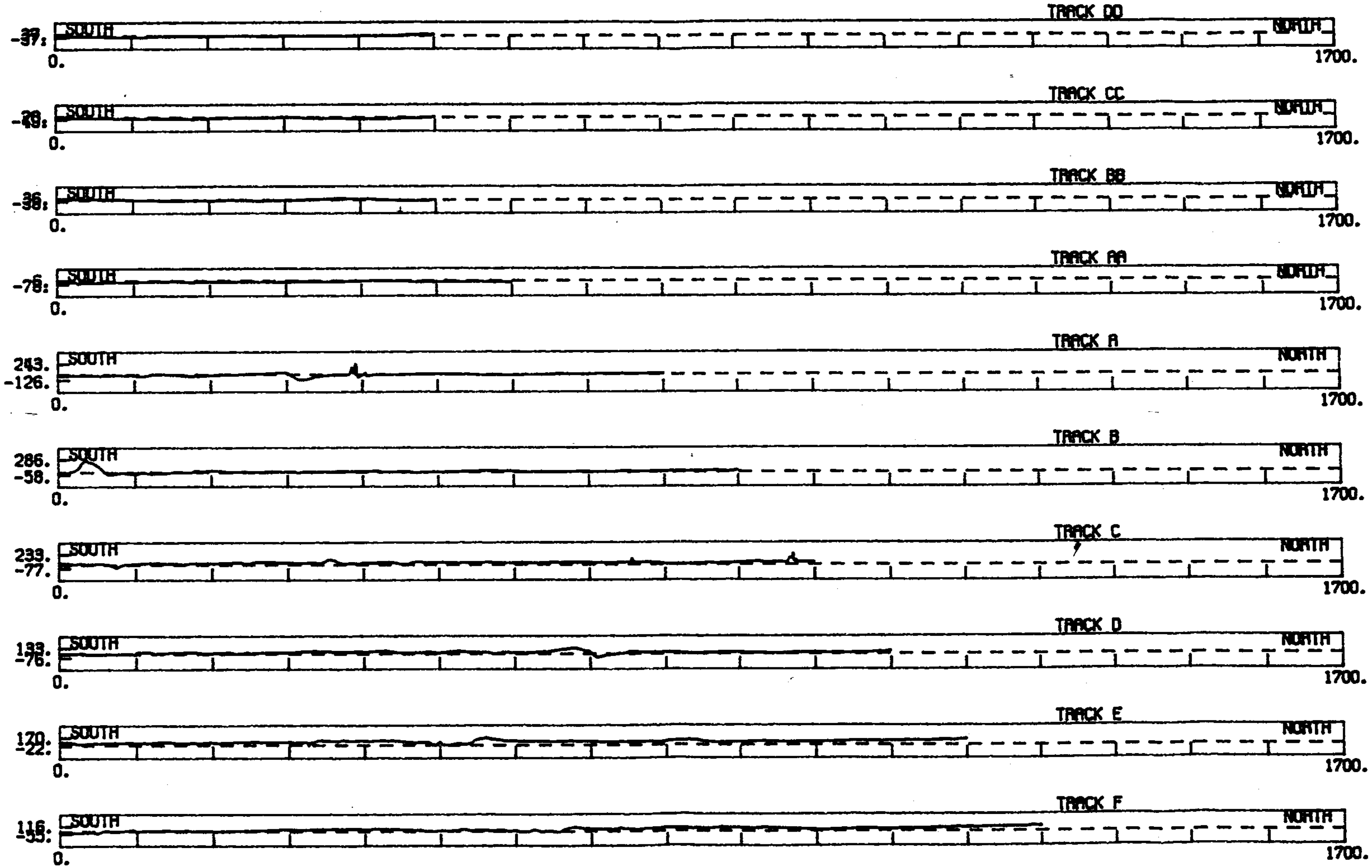


MAGNETIC PROFILES, HORN RAPIDS LANDFILL

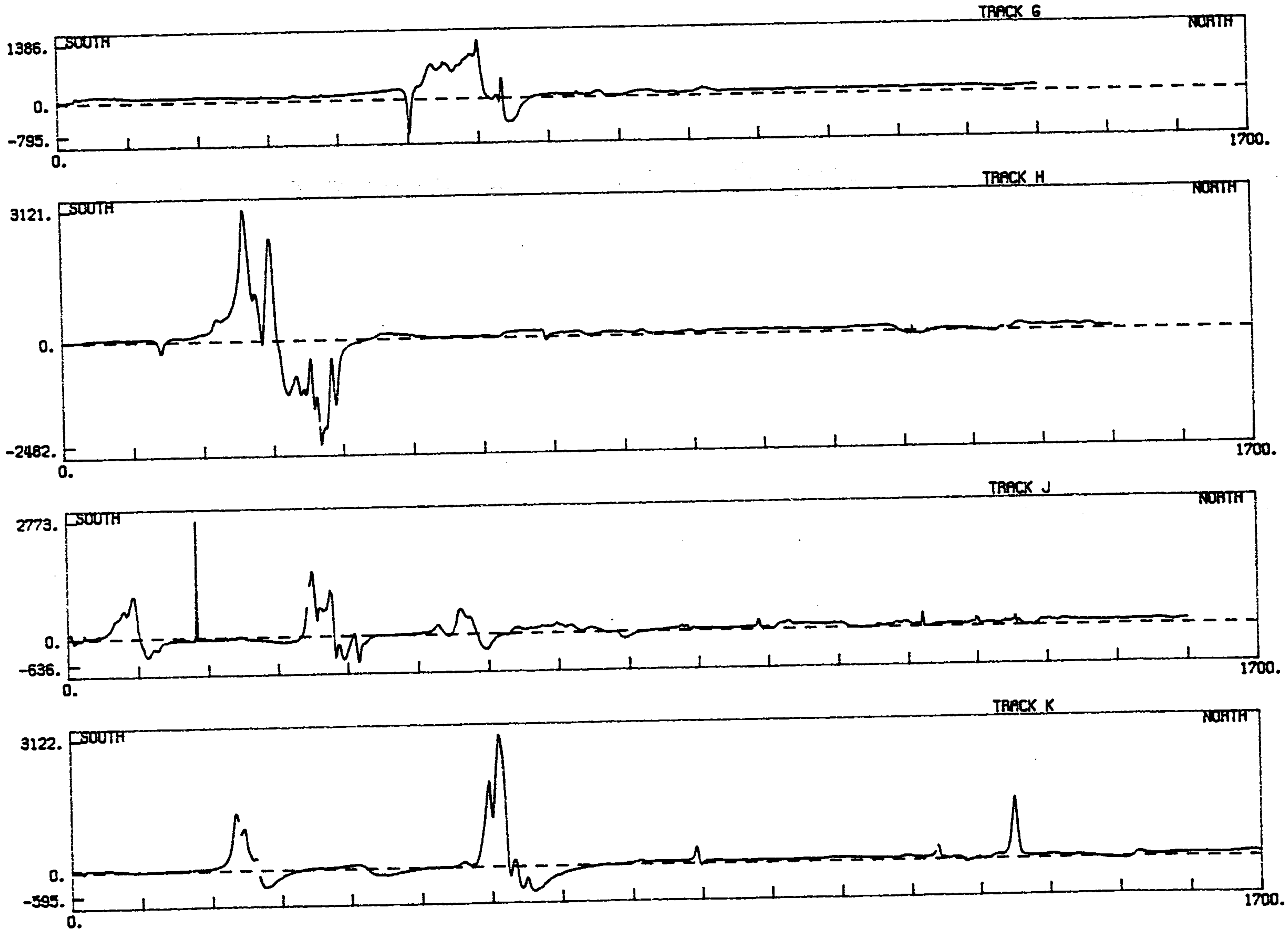


MAGNETIC PROFILES, HORN RAPIDS LANDFILL PAGE 3

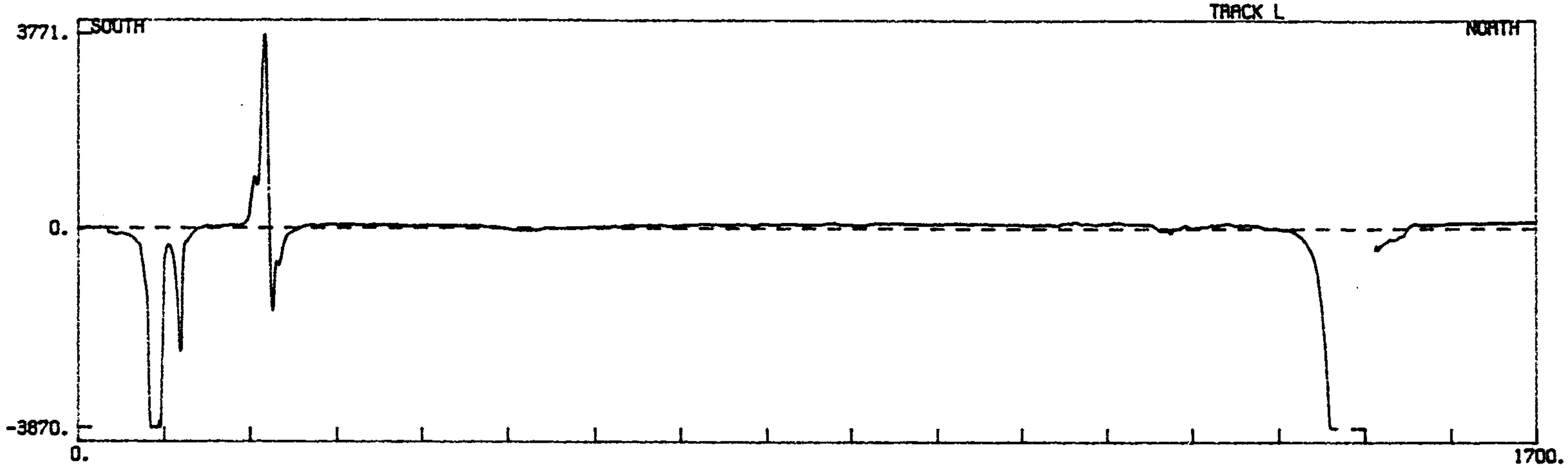


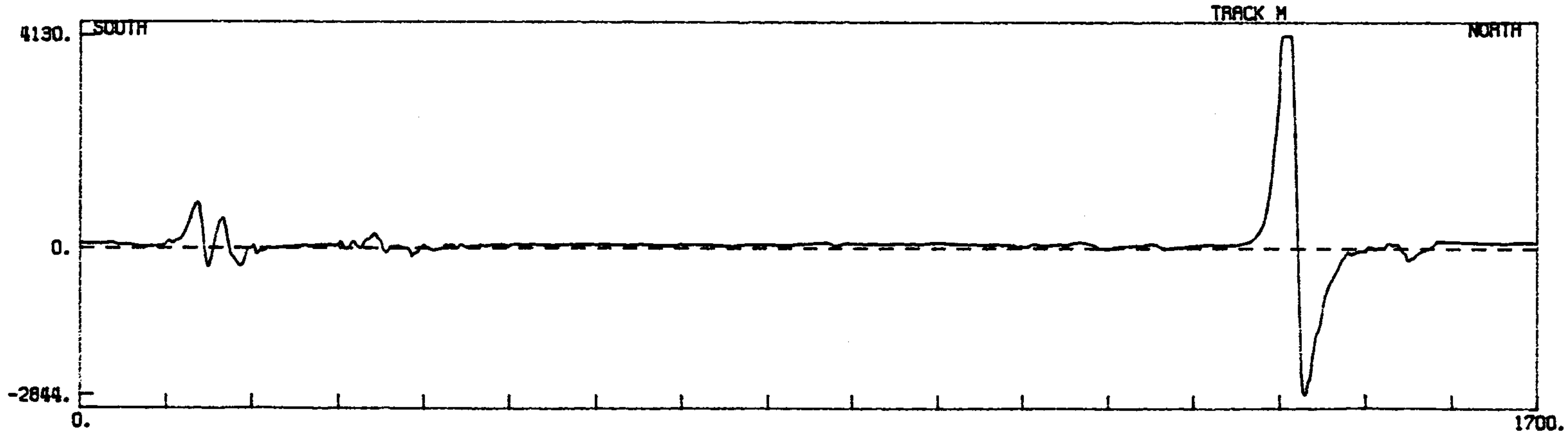

TRACK DD
TRACK CC
TRACK BB
TRACK AA
TRACK A
243.
-126.
TRACK B
286.
-58.
TRACK C
233.
-77.
TRACK D
TRACK E
120.
-22.
TRACK F
SOUTH
NORTH
0.
1700.

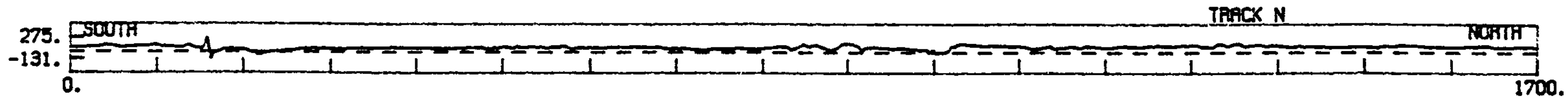
MAGNETIC PROFILES, HORN RAPIDS LANDFILL



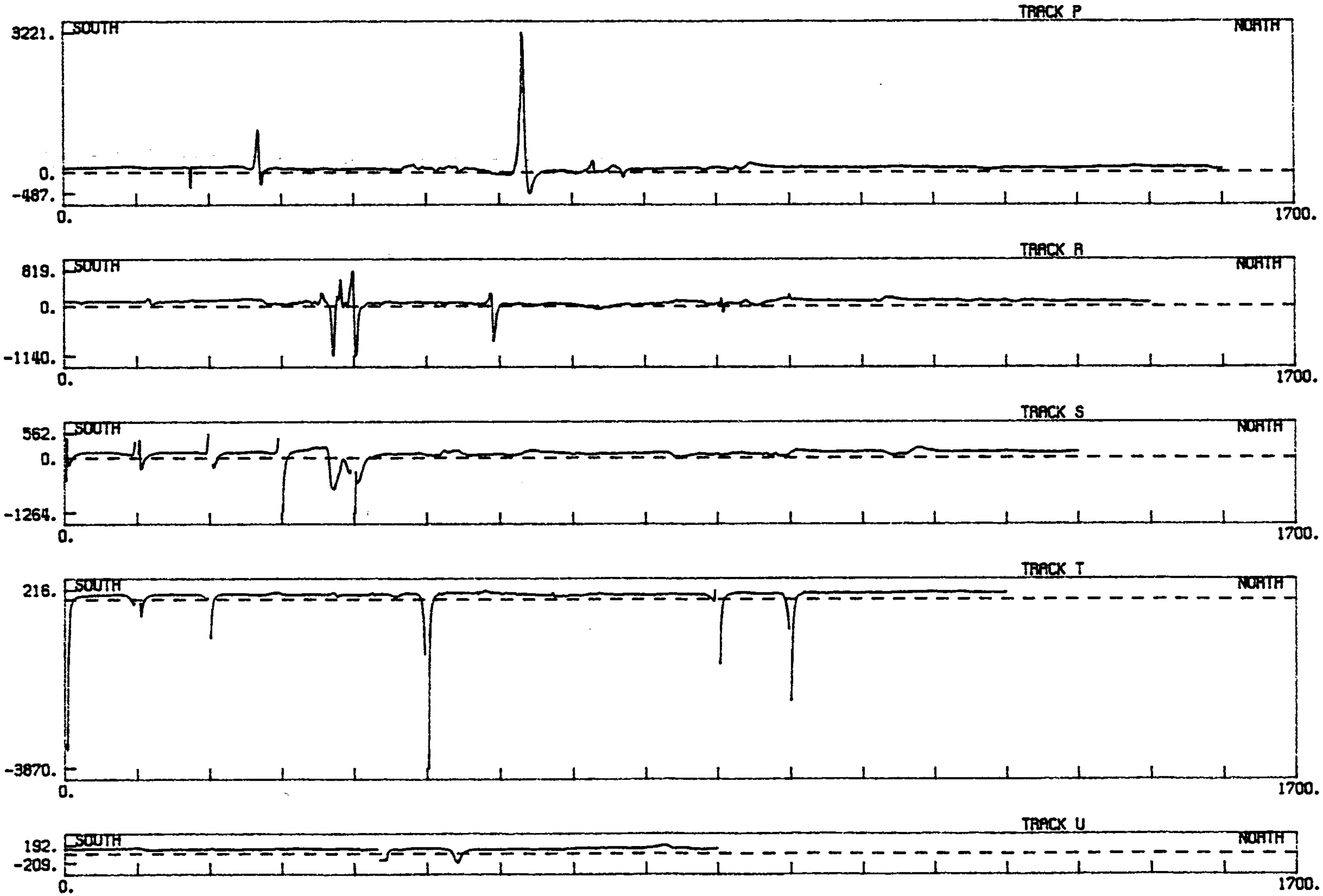
MAGNETIC PROFILES, HORN RAPIDS LANDFILL



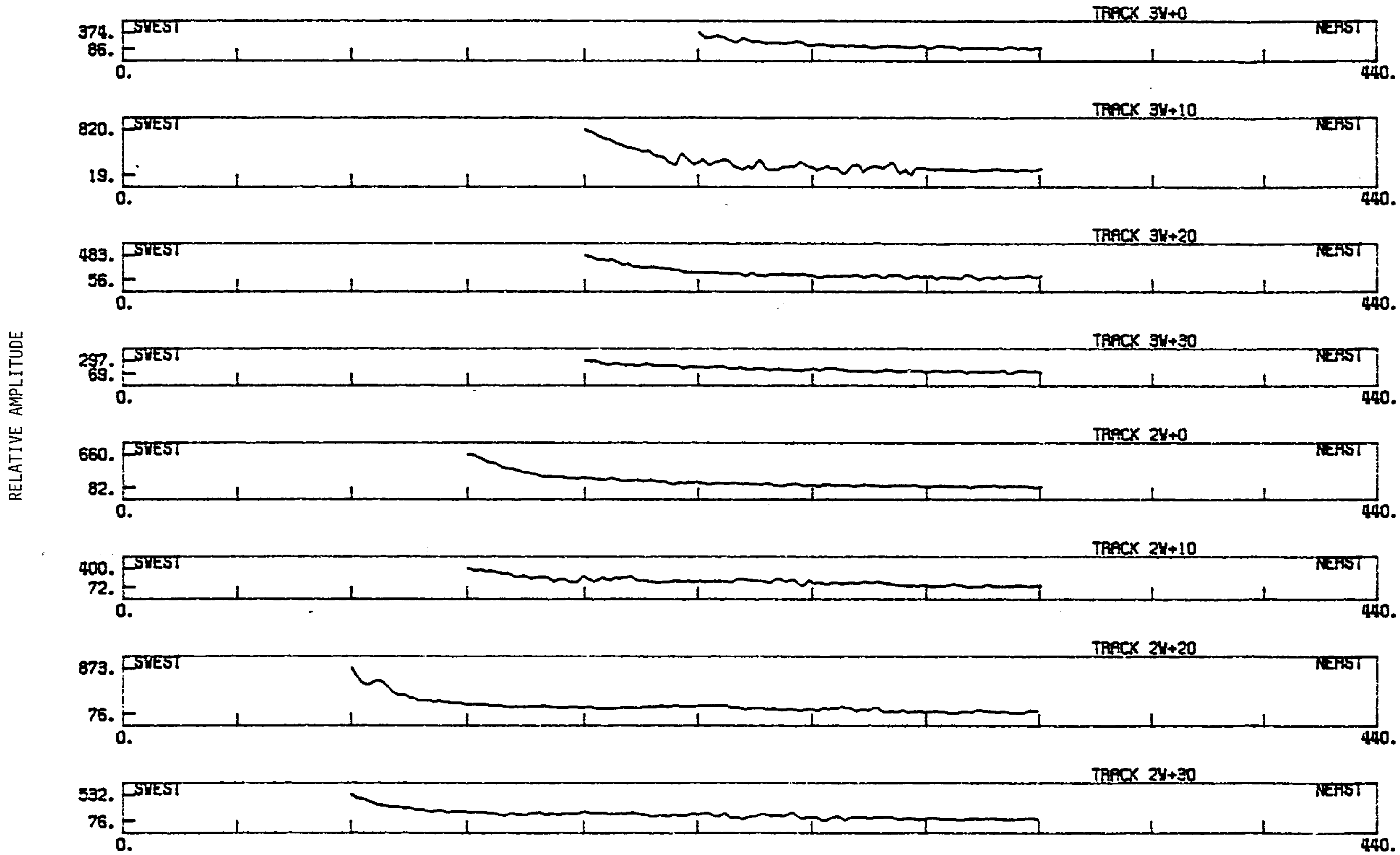




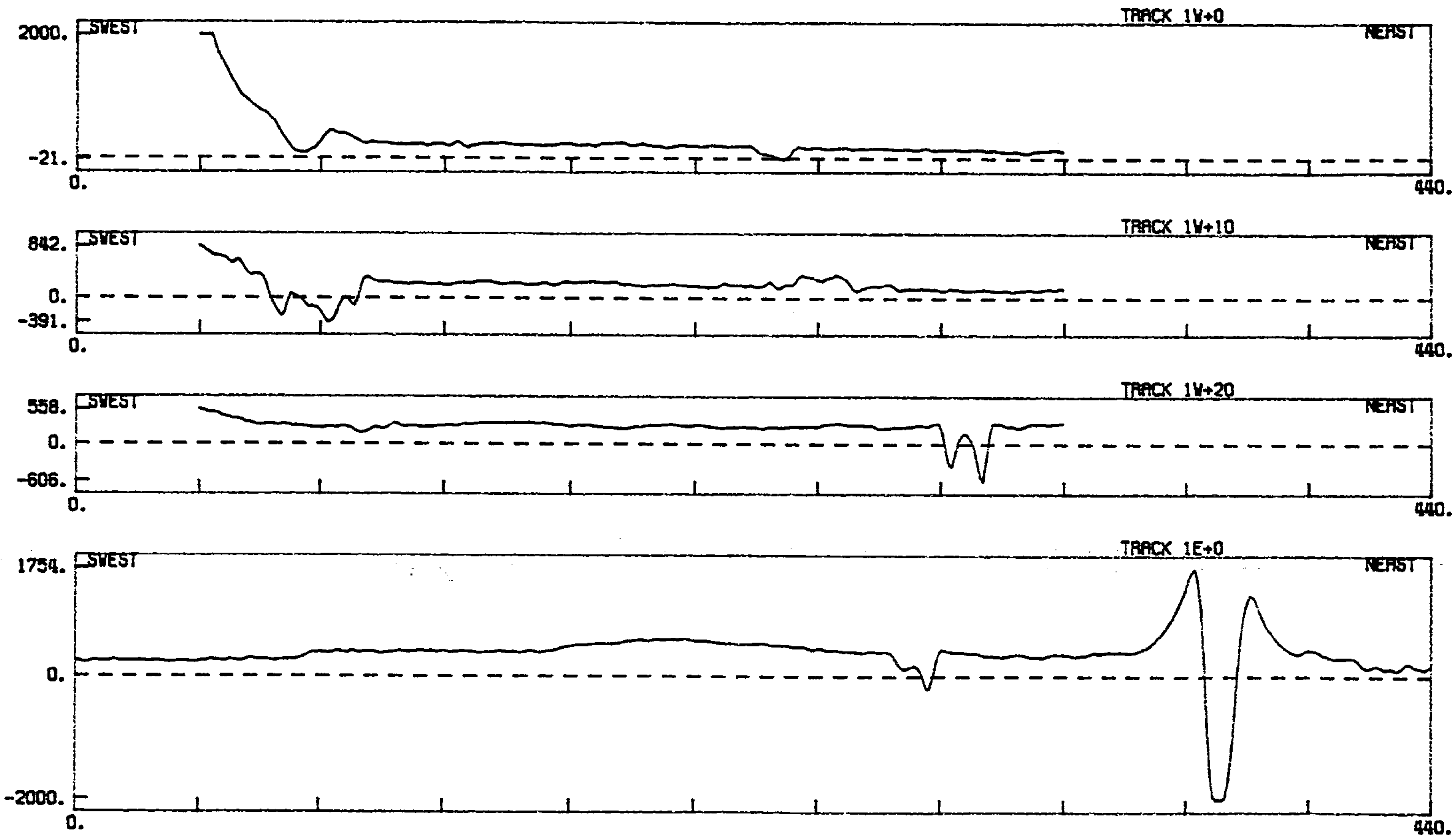
MAGNETIC PROFILES, HORN RAPIDS LANDFILL

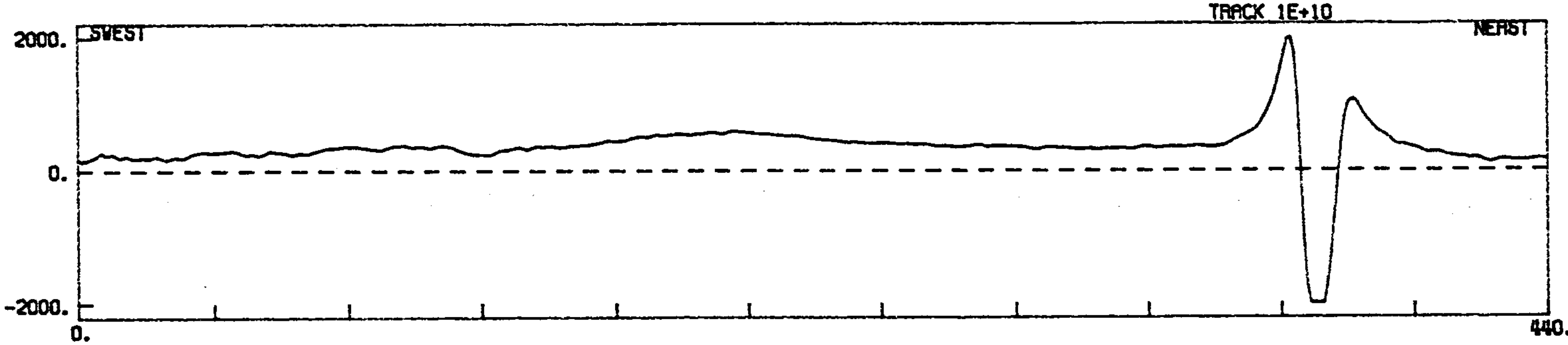


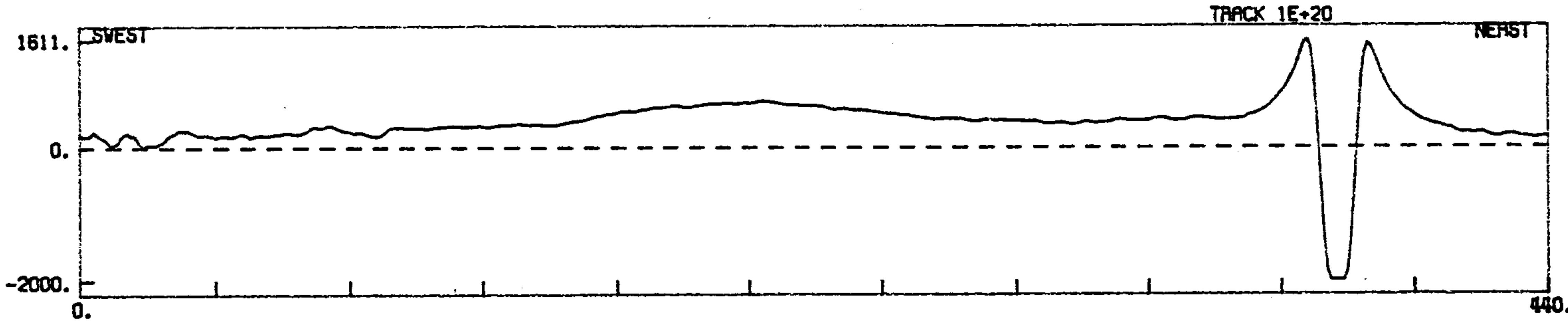
EM PROFILES

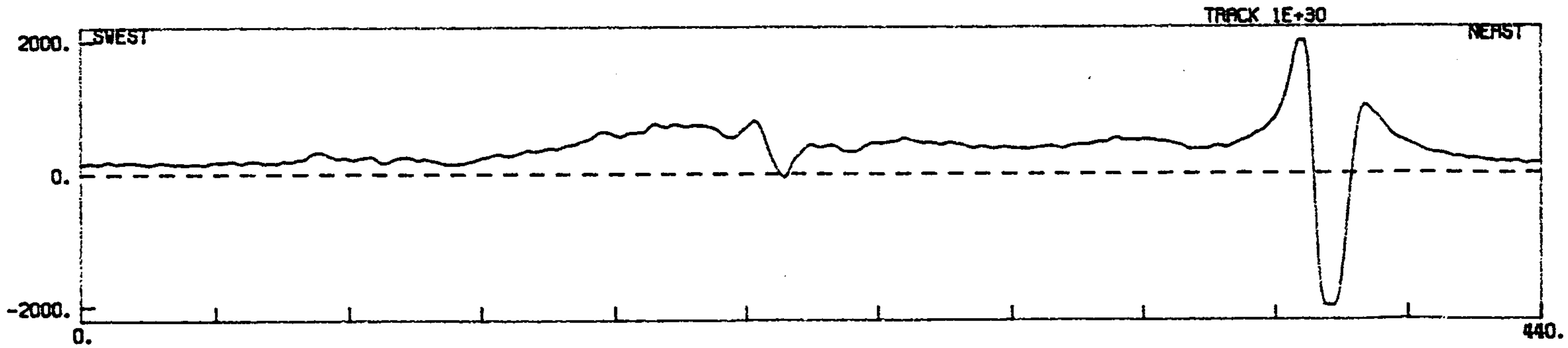

RELATIVE AMPLITUDE
TRACK 3W+0
374.
86.
0.
440.
SWEST
NEAST
TRACK 3W+10
820.
19.
TRACK 3W+20
483.
56.
TRACK 3W+30
297.
69.
TRACK 2W+0
660.
82.
TRACK 2W+10
400.
72.
TRACK 2W+20
873.
76.
TRACK 2W+30
532.
76.

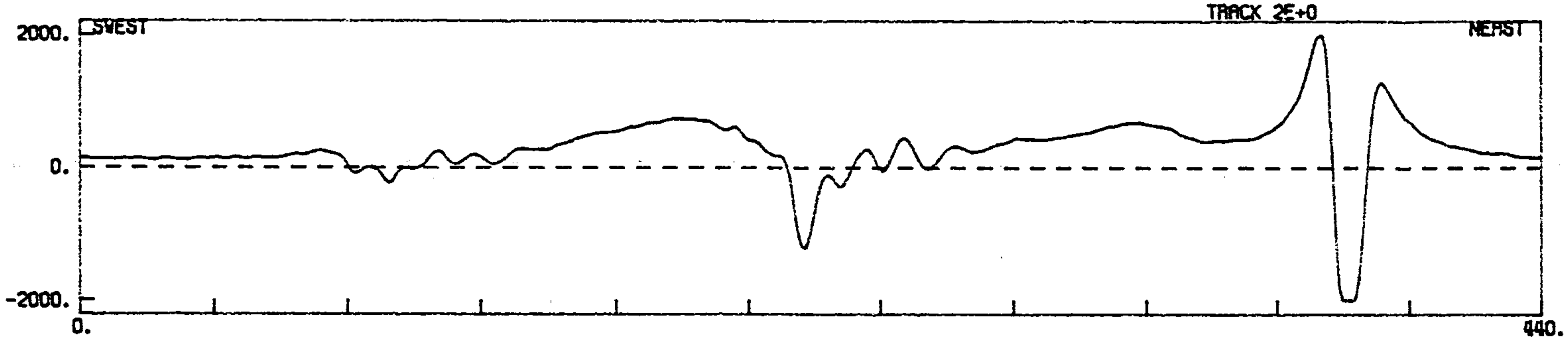
EM31 PROFILES, SITE 1100-2

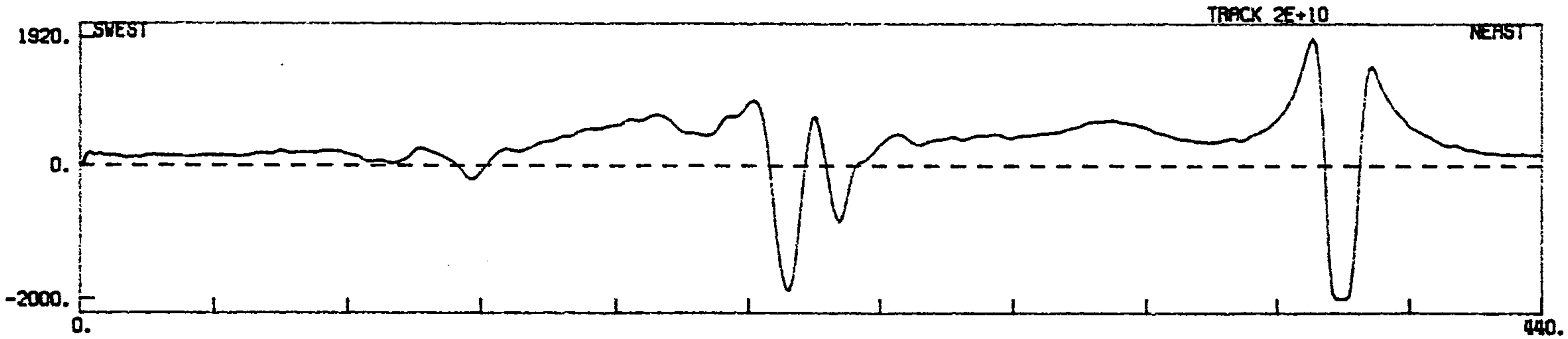


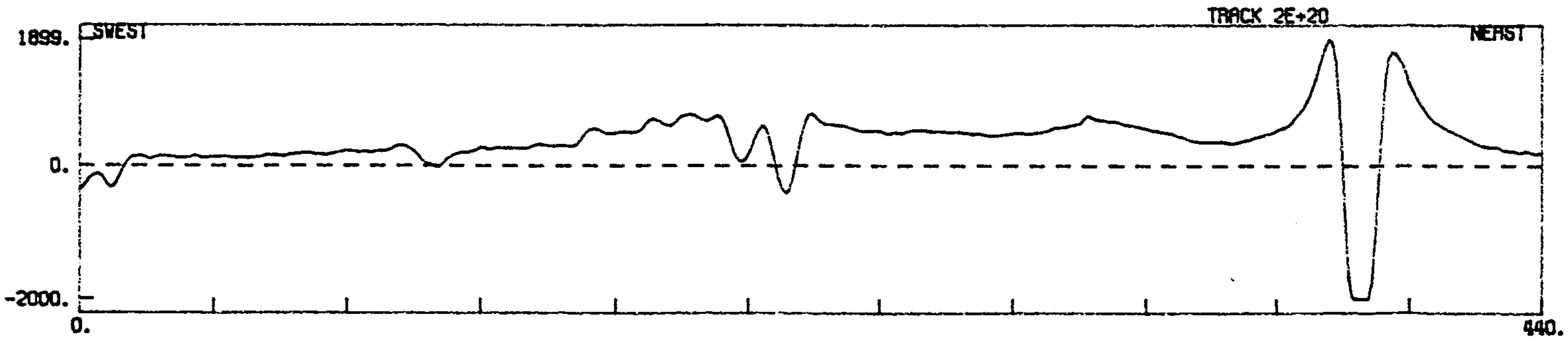

TRACK 1E+10
SWEST
NEAST
2000.
0.
-2000.
0.
440.


TRACK 1E+20
SWEST
NEAST
1611.
0.
-2000.
0.
440.

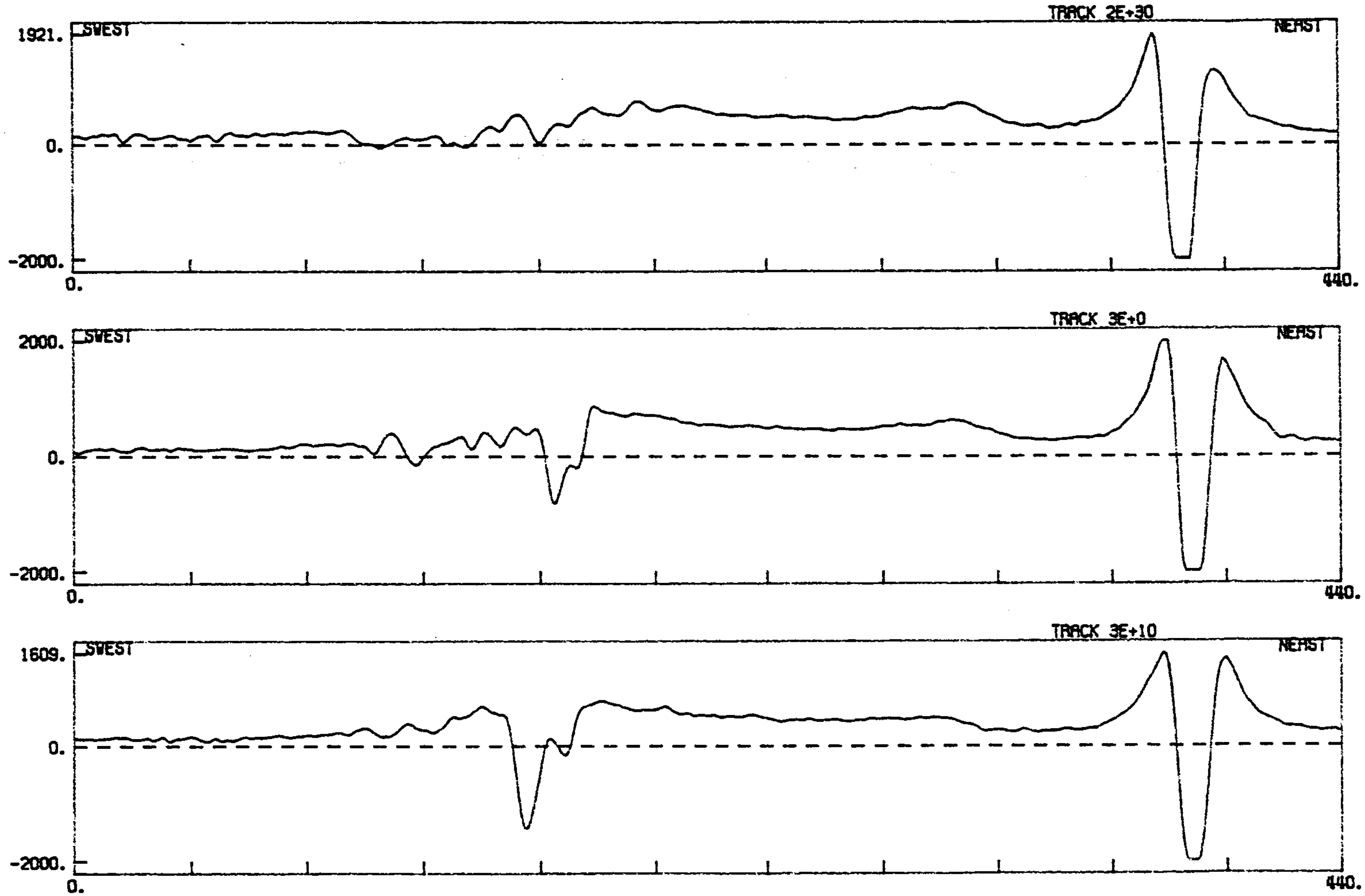

TRACK 1E+30
SWEST
NEAST
2000.
0.
-2000.
0.
440.

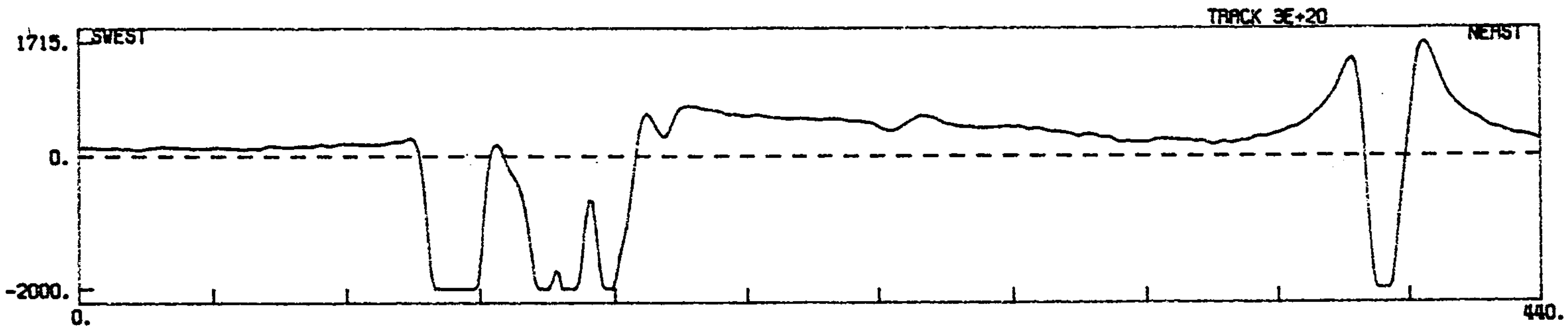

TRACK 2E+0
SWEST
NEAST
2000.
0.
-2000.
0.
440.

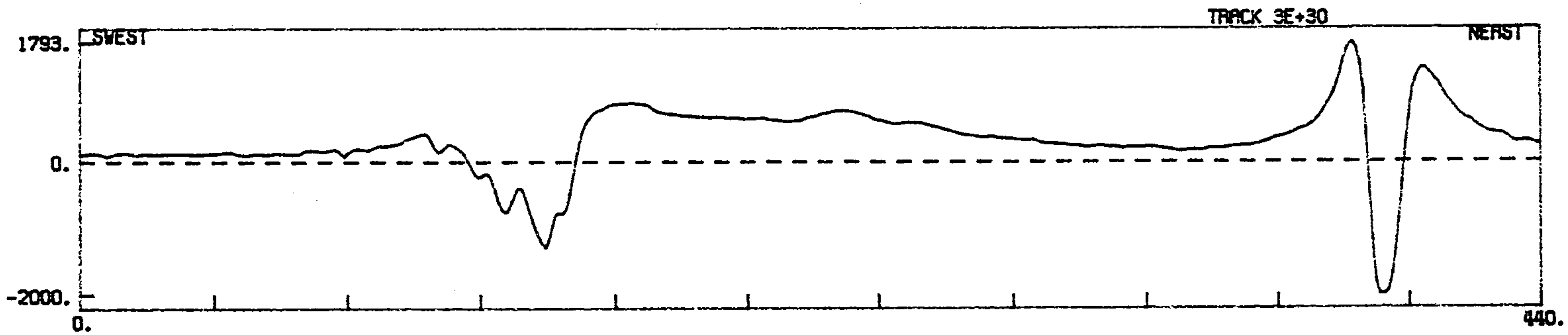

TRACK 2E+10
SWEST
NEAST
1920.
0.
-2000.
0.
440.

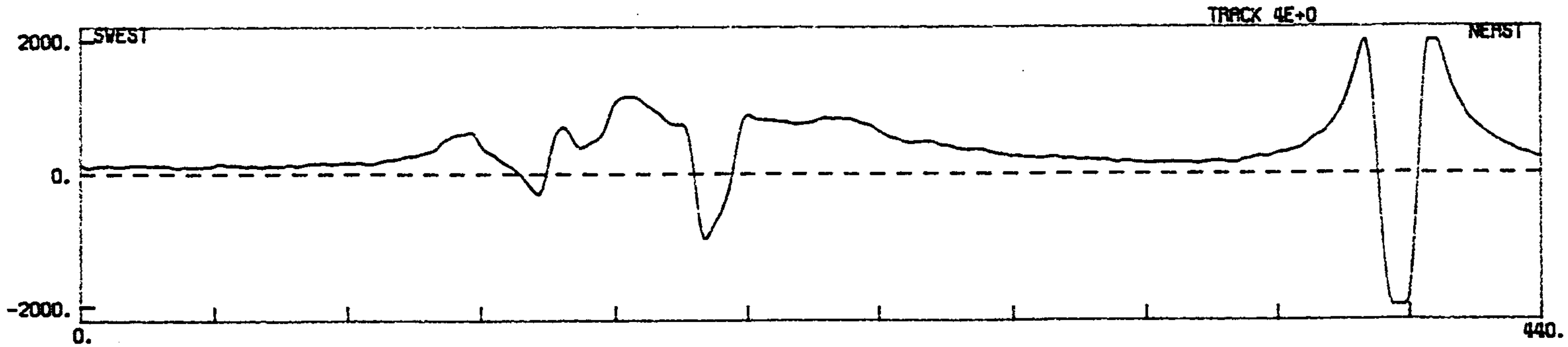

TRACK 2E+20
SWEST
NEAST
1899.
0.
-2000.
0.
440.

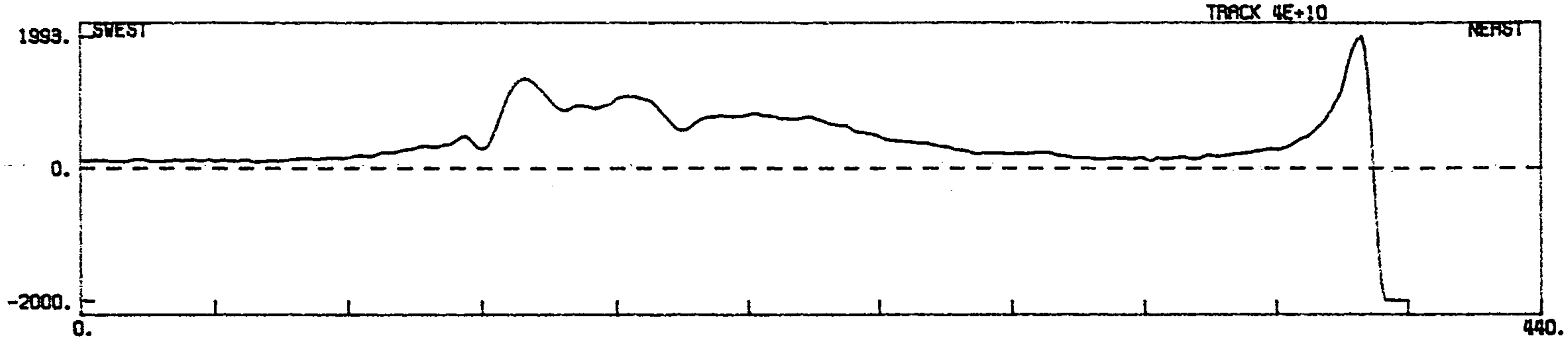
EM31 PROFILES, SITE 1100-2

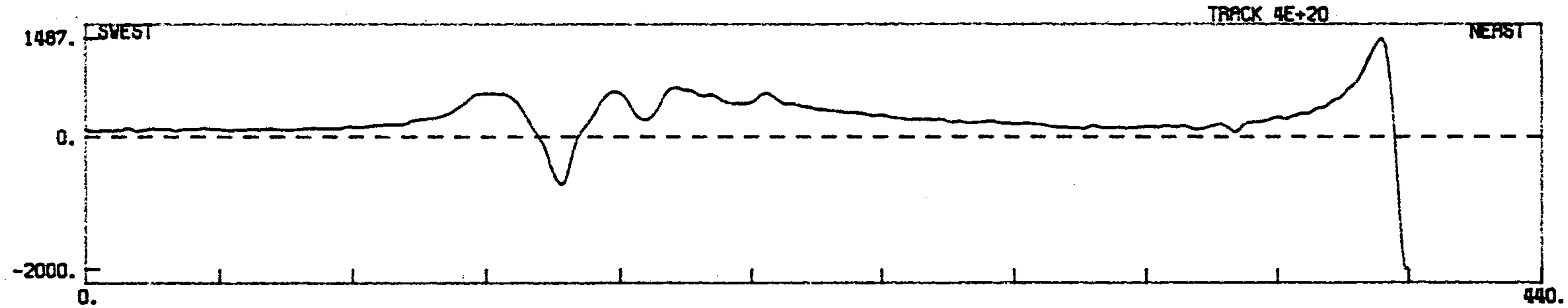


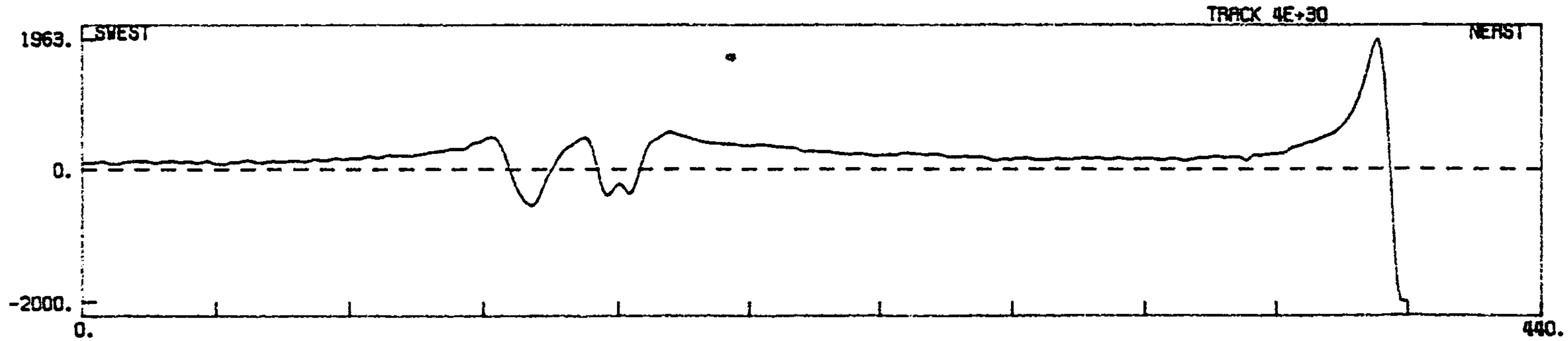

TRACK 3E+20
SWEST
NEAST
1715.
0.
-2000.
0.
440.

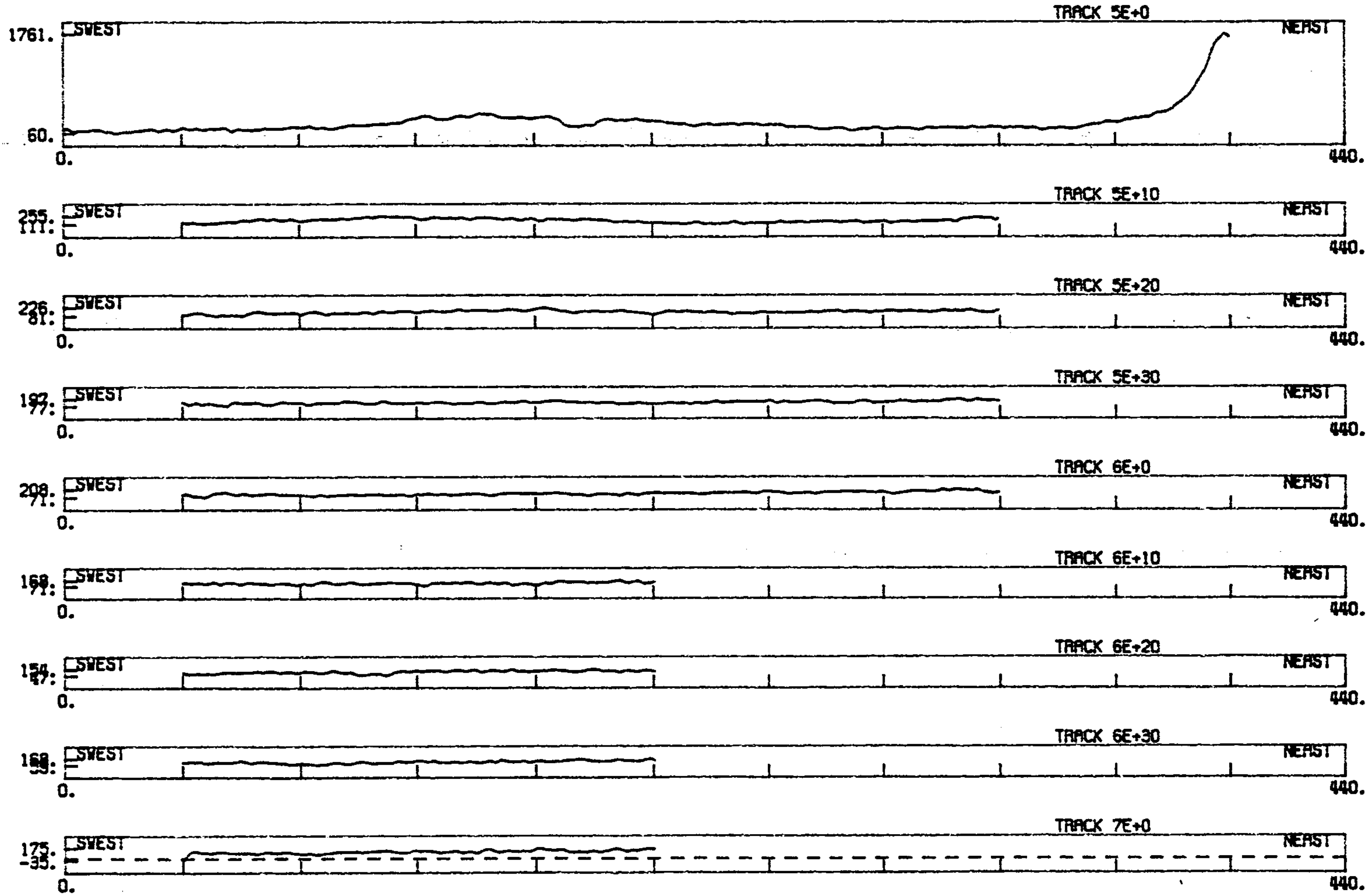

TRACK 3E+30
SWEST
NEAST
1793.
0.
-2000.
0.
440.

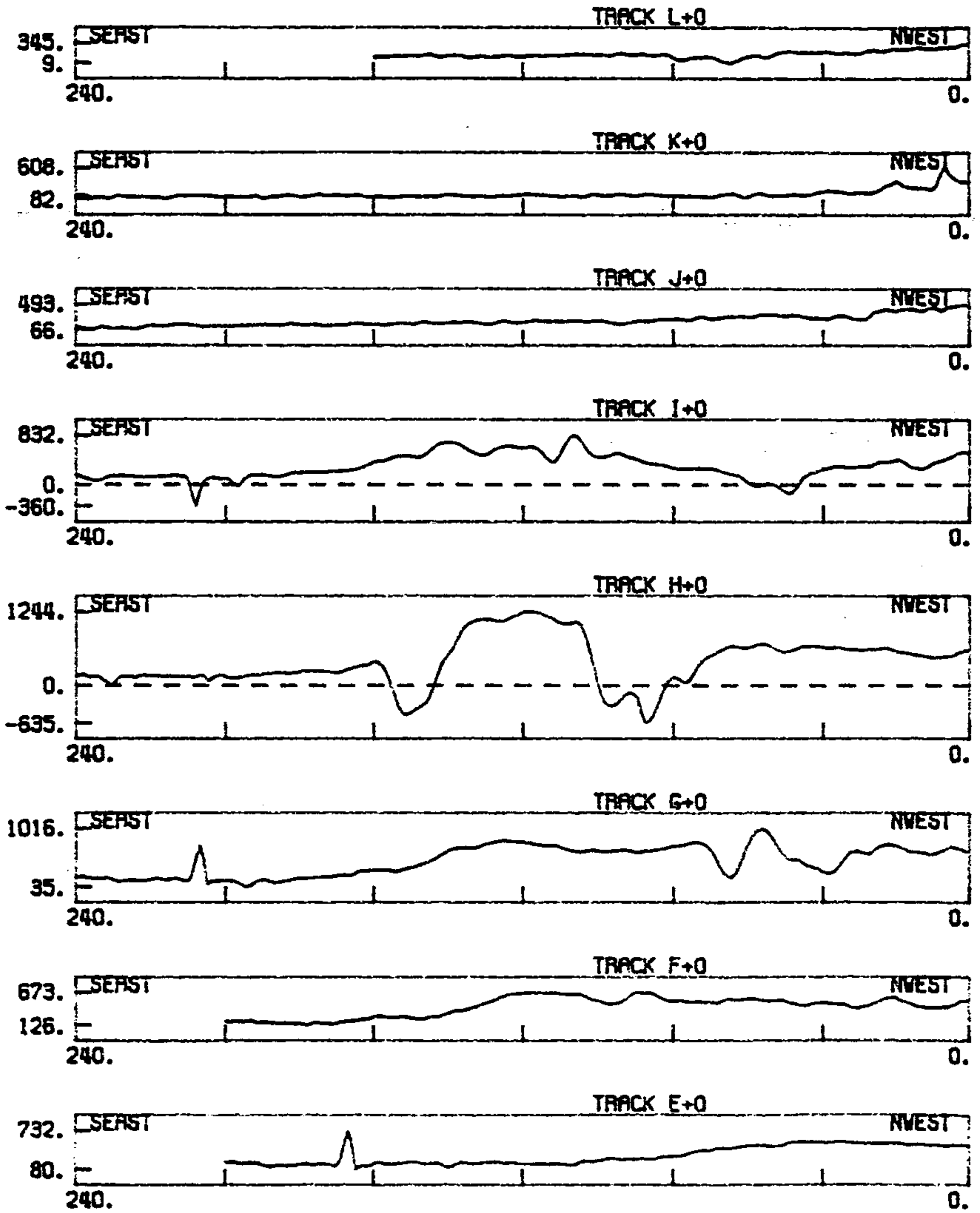

TRACK 4E+0
SWEST
NEAST
2000.
0.
-2000.
0.
440.


TRACK 4E+10
SWEST
NEAST
1993.
0.
-2000.
0.
440.

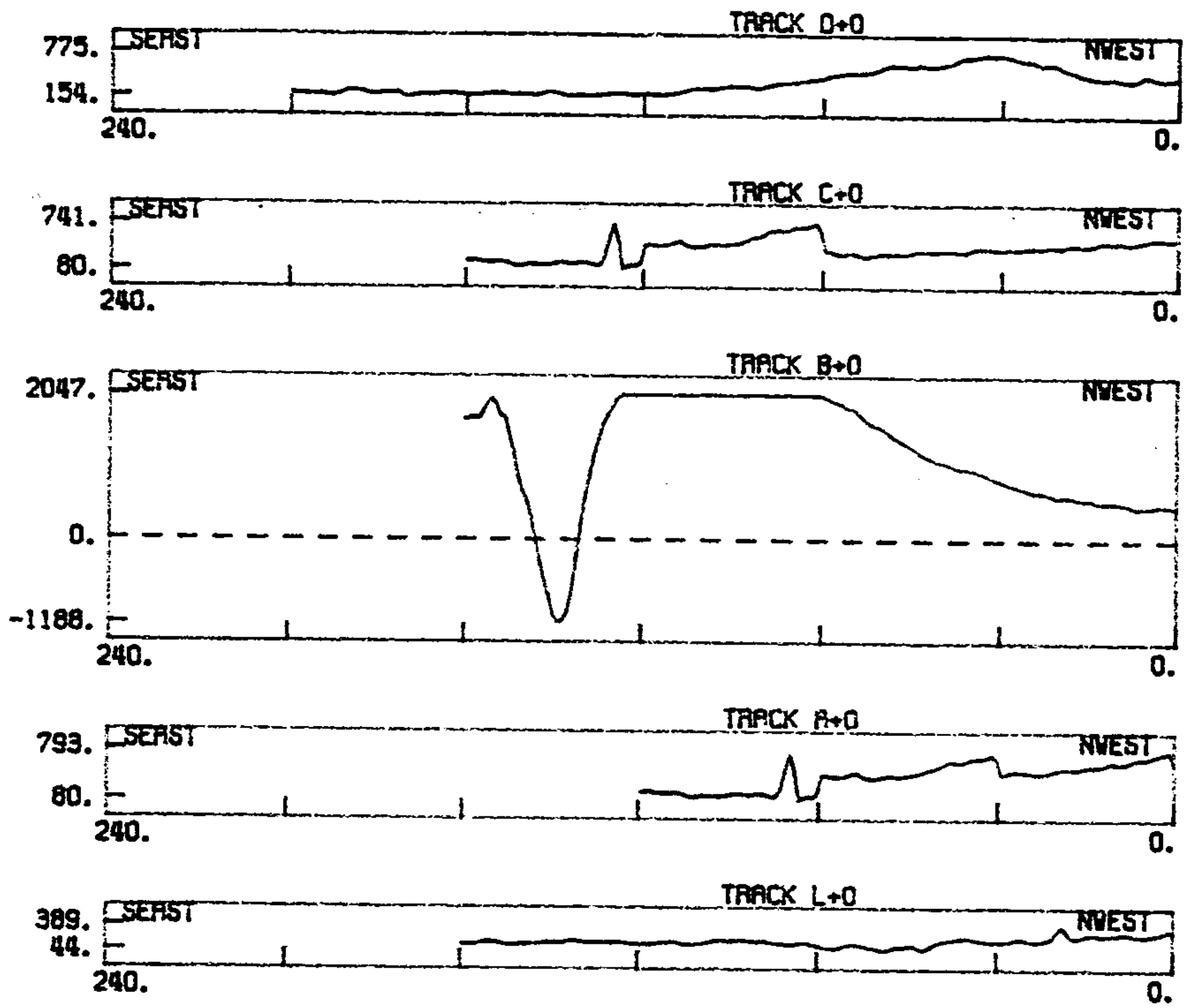

TRACK 4E+20
SWEST
NEAST
1487.
0.
-2000.
0.
440.

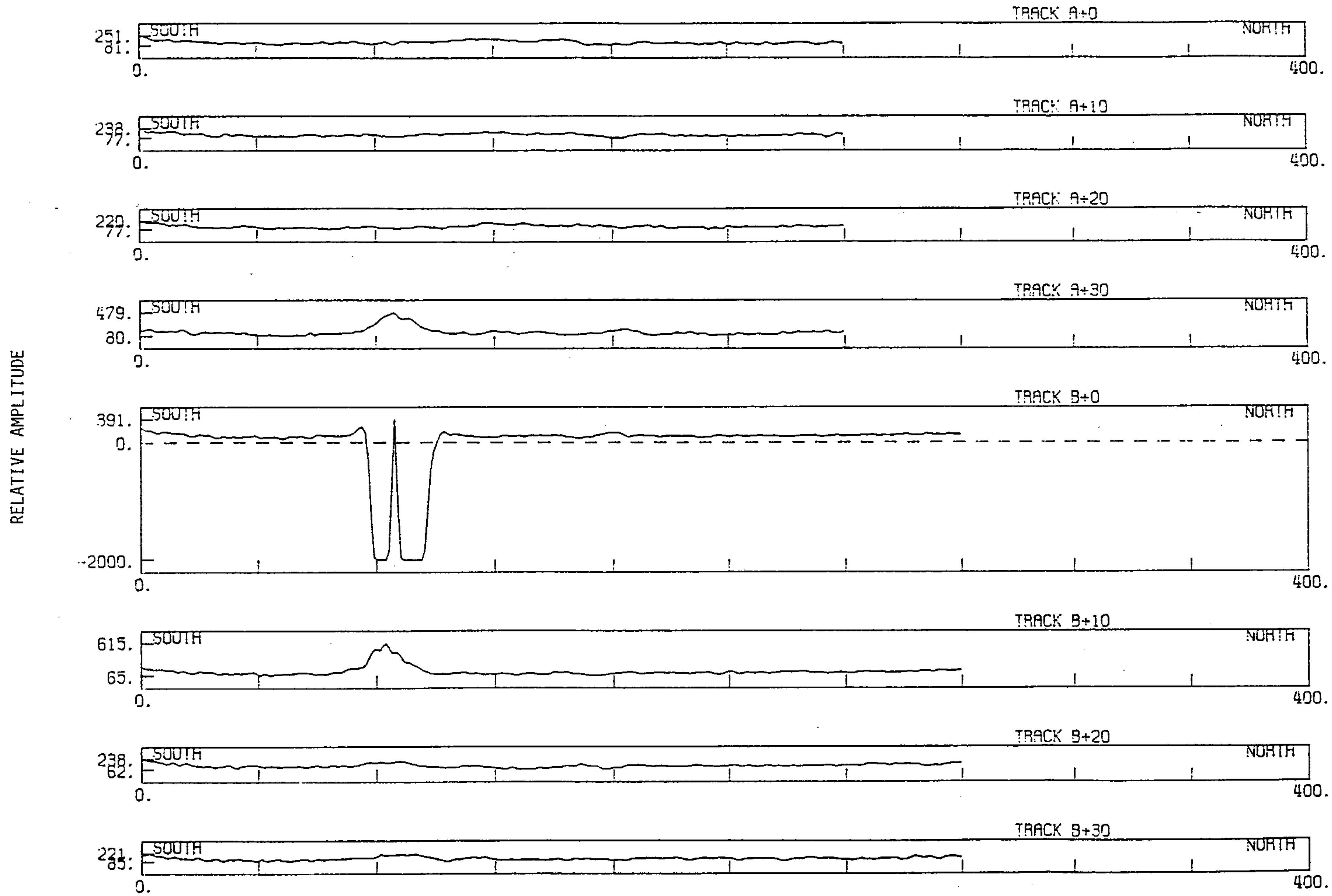

TRACK 4E+30
SWEST
NEAST
1963.
0.
-2000.
0.
440.

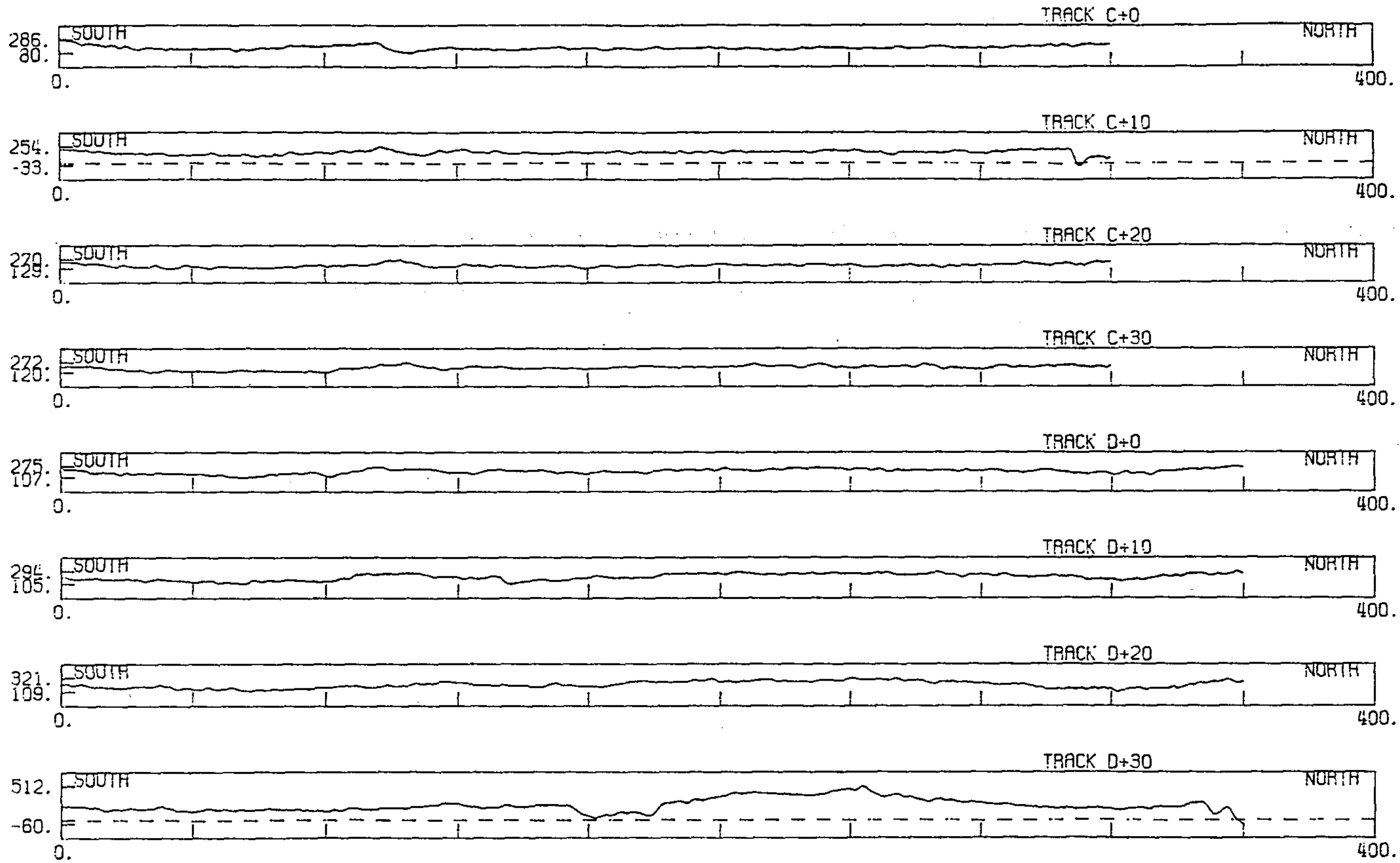

TRACK 5E+0
SWEST
NEAST
1761.
60.
0.
440.
TRACK 5E+10
SWEST
NEAST
255.
111.
0.
440.
TRACK 5E+20
SWEST
NEAST
226.
81.
0.
440.
TRACK 5E+30
SWEST
NEAST
192.
77.
0.
440.
TRACK 6E+0
SWEST
NEAST
208.
71.
0.
440.
TRACK 6E+10
SWEST
NEAST
168.
71.
0.
440.
TRACK 6E+20
SWEST
NEAST
154.
47.
0.
440.
TRACK 6E+30
SWEST
NEAST
168.
0.
440.
TRACK 7E+0
SWEST
NEAST
175.
-35.
0.
440.


TRACK L+0
345.
9.
SEAST
NWEST
240.
0.
TRACK K+0
608.
82.
SEAST
NWEST
240.
0.
TRACK J+0
493.
66.
SEAST
NWEST
240.
0.
TRACK I+0
832.
0.
-360.
SEAST
NWEST
240.
0.
TRACK H+0
1244.
0.
-635.
SEAST
NWEST
240.
0.
TRACK G+0
1016.
35.
SEAST
NWEST
240.
0.
TRACK F+0
673.
126.
SEAST
NWEST
240.
0.
TRACK E+0
732.
80.
SEAST
NWEST
240.
0.

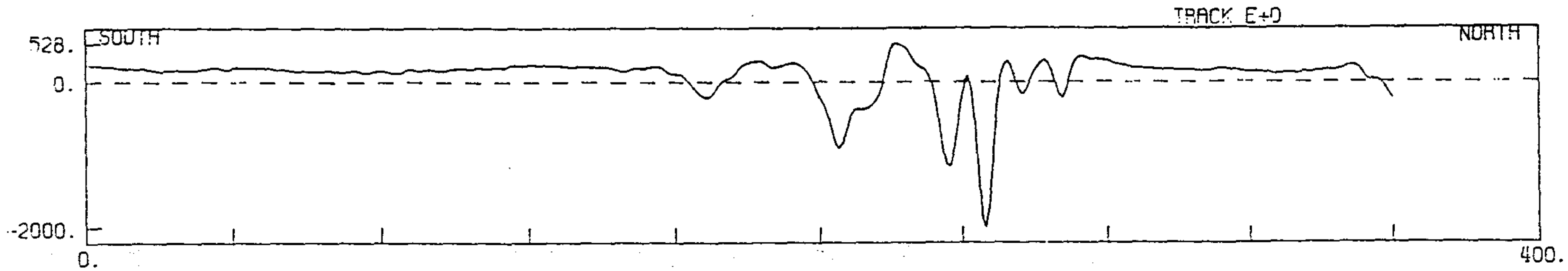
EM31 PROFILES, SITE 1100-2

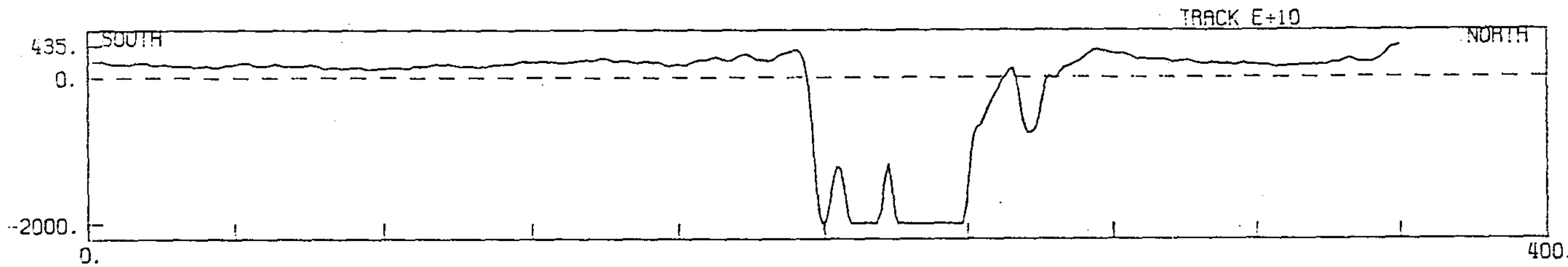


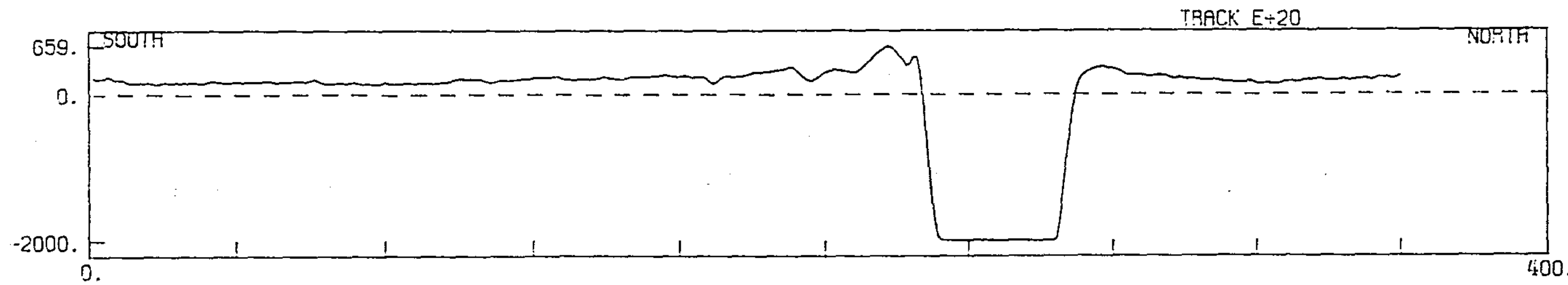

RELATIVE AMPLITUDE
TRACK A+0
SOUTH
NORTH
251.
81.
0.
400.
TRACK A+10
238.
77.
TRACK A+20
220.
77.
TRACK A+30
479.
80.
TRACK B+0
391.
0.
-2000.
TRACK B+10
615.
65.
TRACK B+20
238.
62.
TRACK B+30
221.
85.

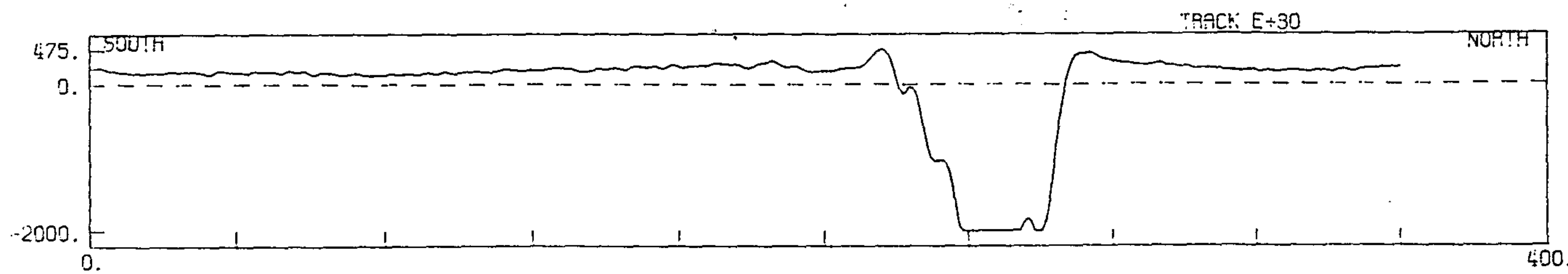

TRACK C+0
SOUTH
NORTH
286.
80.
0.
400.
TRACK C+10
SOUTH
NORTH
254.
-33.
0.
400.
TRACK C+20
SOUTH
NORTH
270.
129.
0.
400.
TRACK C+30
SOUTH
NORTH
272.
120.
0.
400.
TRACK D+0
SOUTH
NORTH
275.
107.
0.
400.
TRACK D+10
SOUTH
NORTH
294.
105.
0.
400.
TRACK D+20
SOUTH
NORTH
321.
109.
0.
400.
TRACK D+30
SOUTH
NORTH
512.
-60.
0.
400.

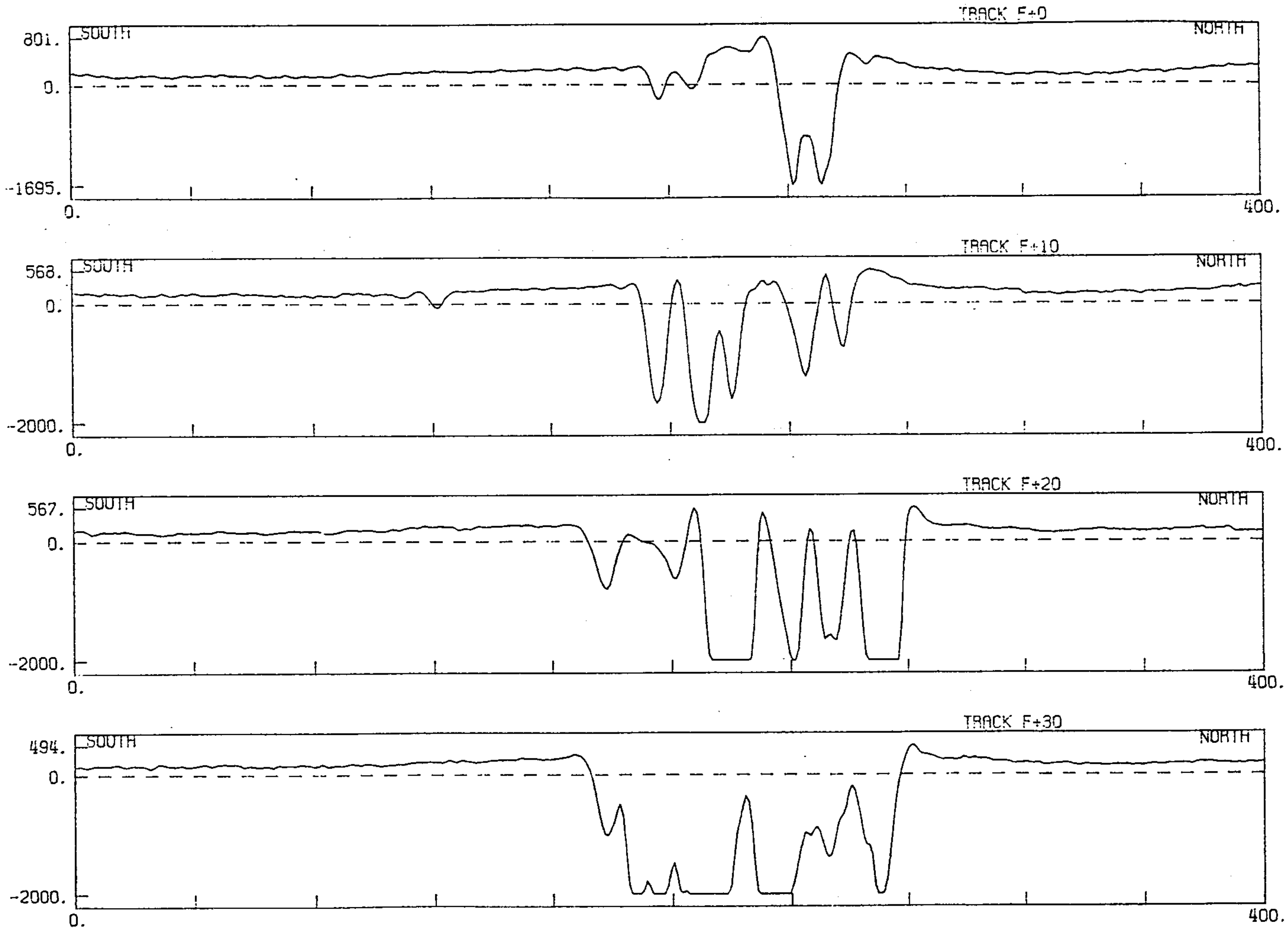
EM31 PROFILES, SITE 1100-3

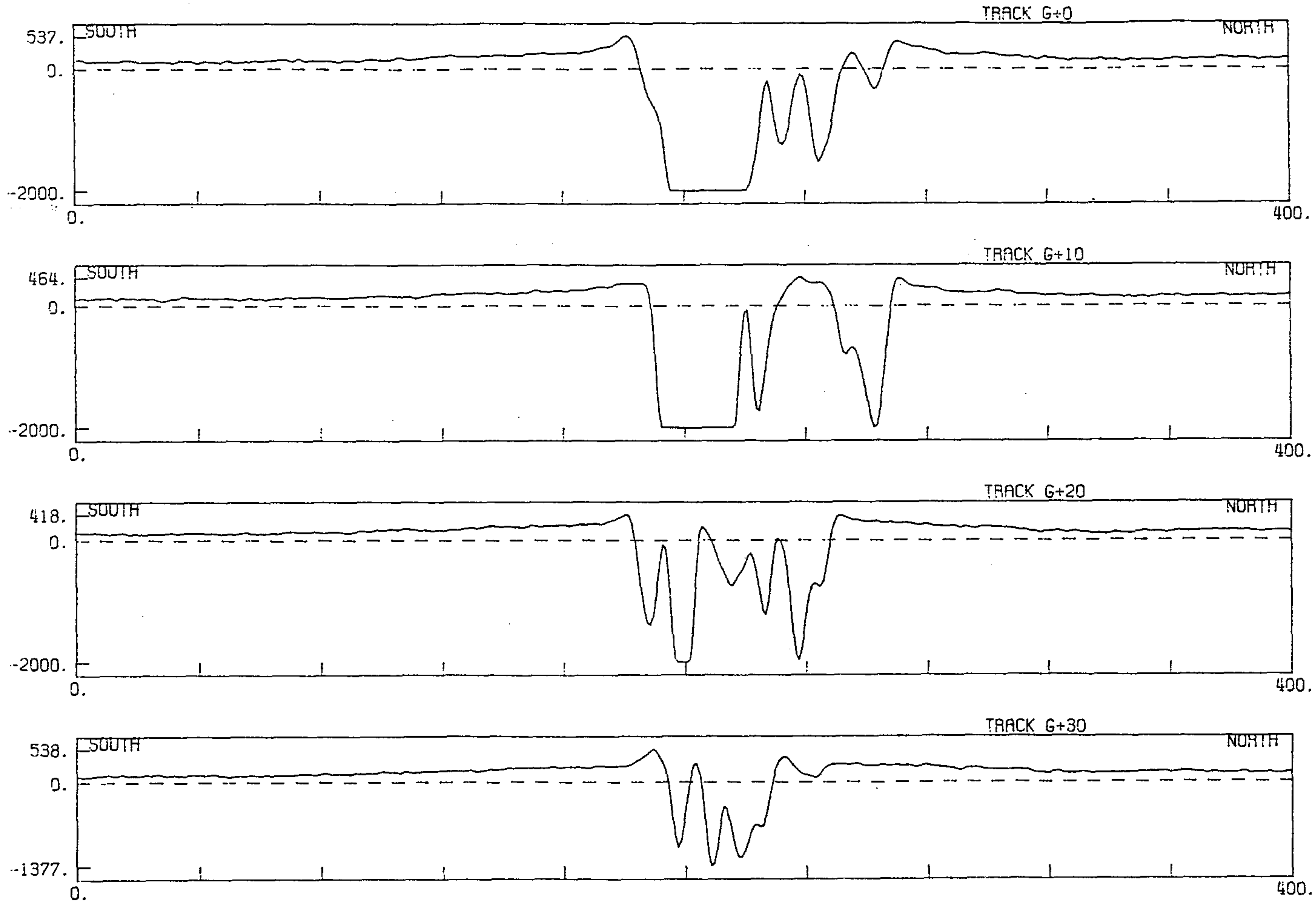




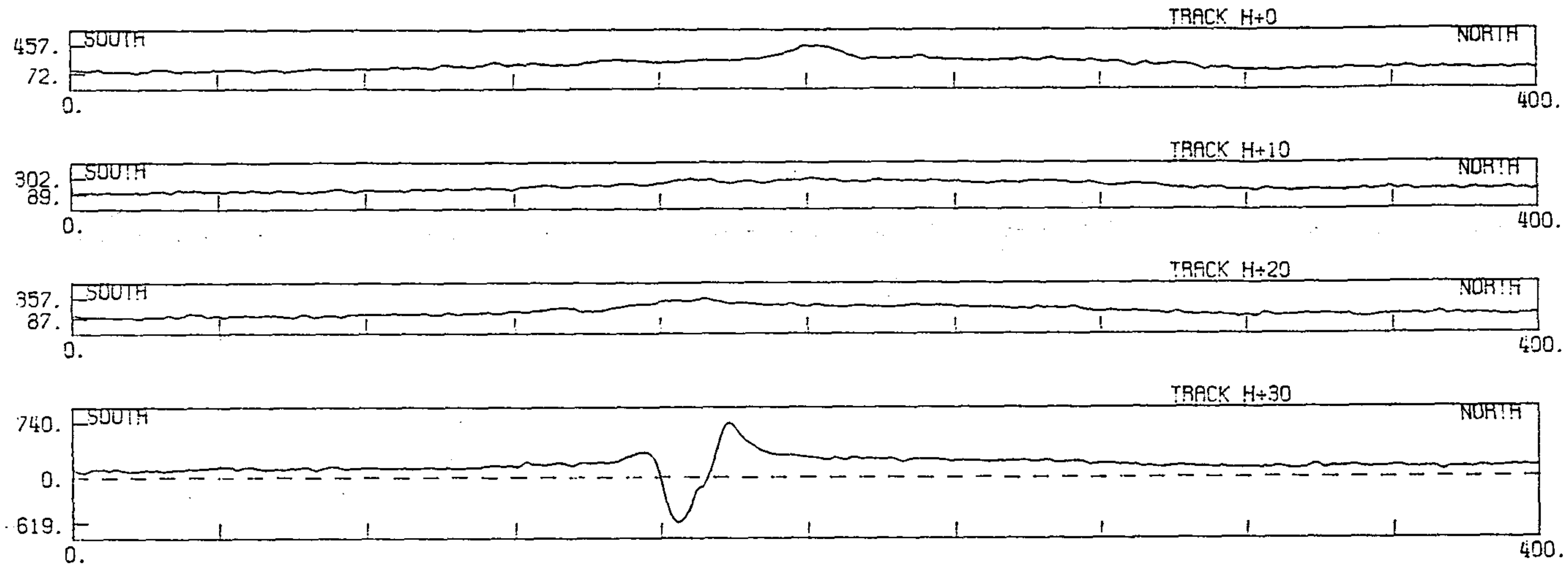


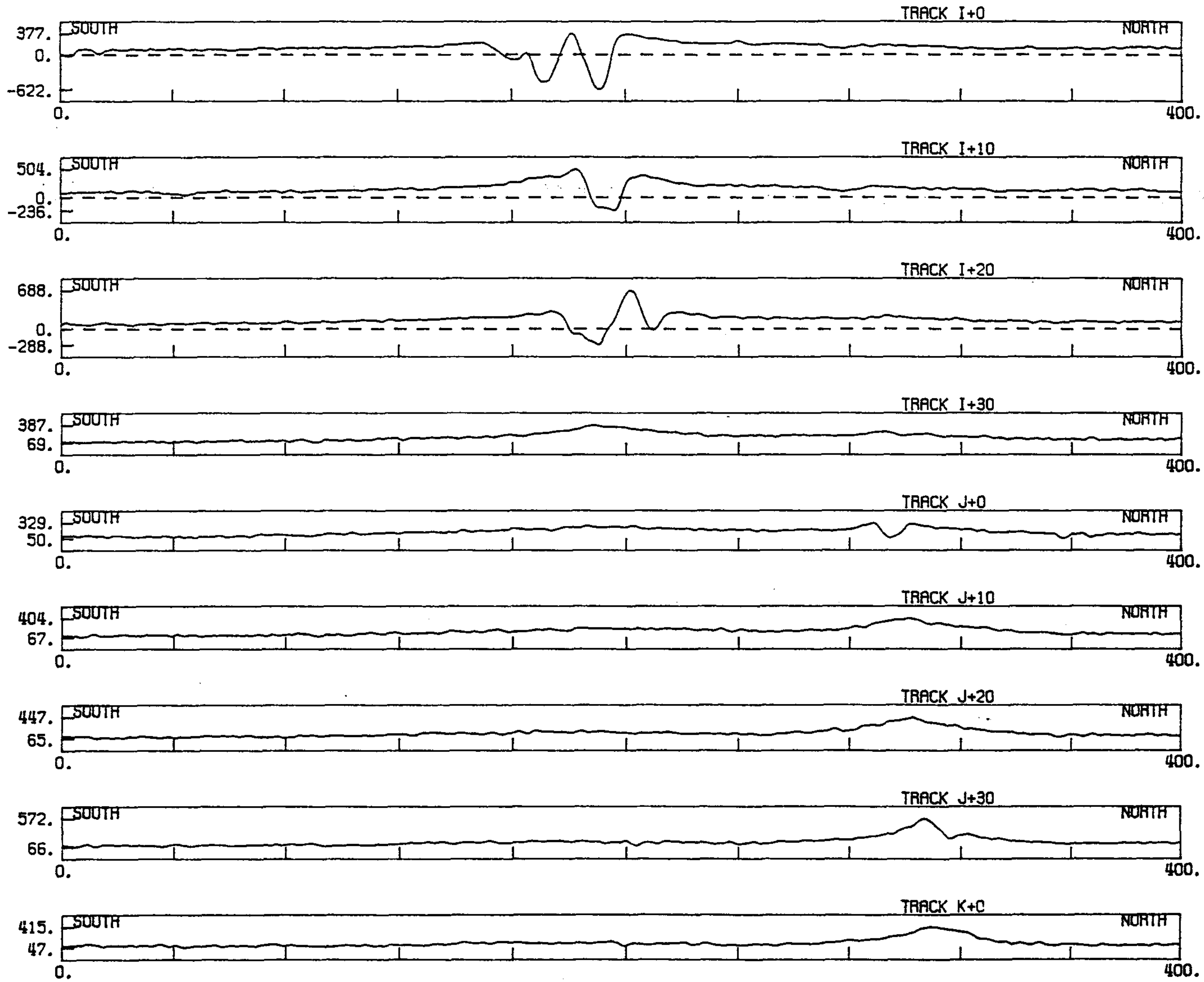


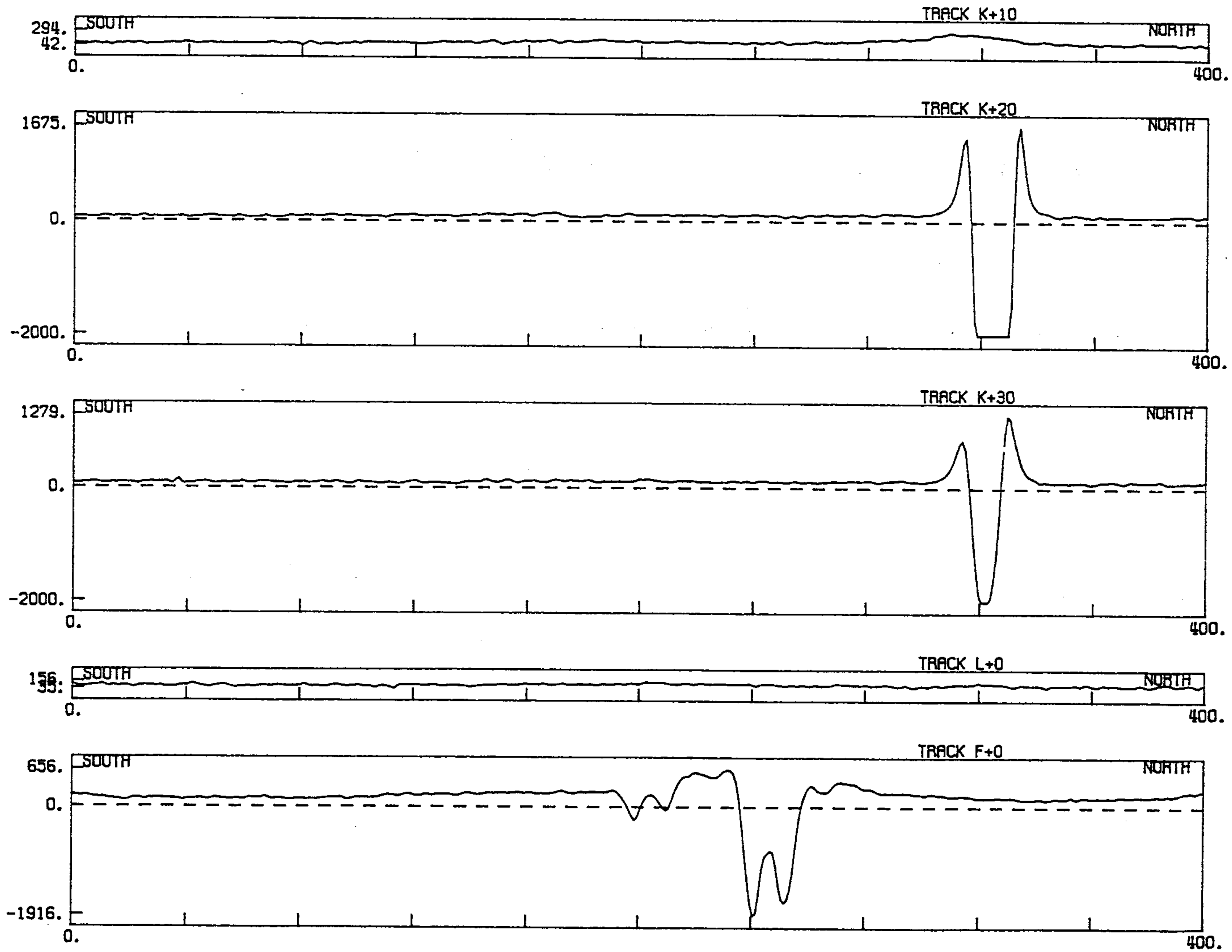

TRACK F+0
SOUTH
NORTH
801.
0.
-1695.
0.
400.
TRACK F+10
SOUTH
NORTH
568.
0.
-2000.
0.
400.
TRACK F+20
SOUTH
NORTH
567.
0.
-2000.
0.
400.
TRACK F+30
SOUTH
NORTH
494.
0.
-2000.
0.
400.

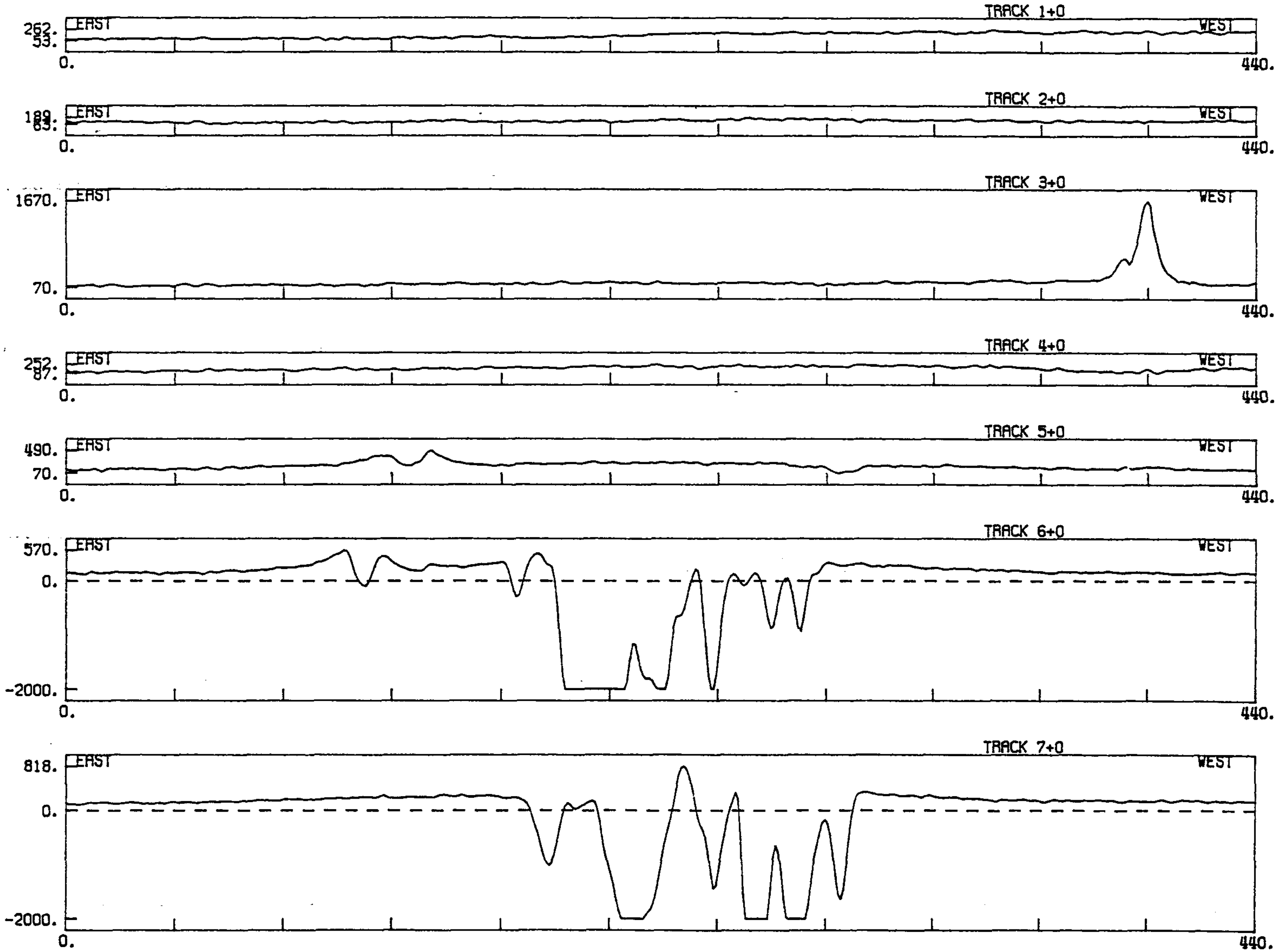

TRACK G+0
SOUTH
NORTH
537.
0.
-2000.
0.
400.
TRACK G+10
SOUTH
NORTH
464.
0.
-2000.
0.
400.
TRACK G+20
SOUTH
NORTH
418.
0.
-2000.
0.
400.
TRACK G+30
SOUTH
NORTH
538.
0.
-1377.
0.
400.

EM31 PROFILES, SITE 1100-3

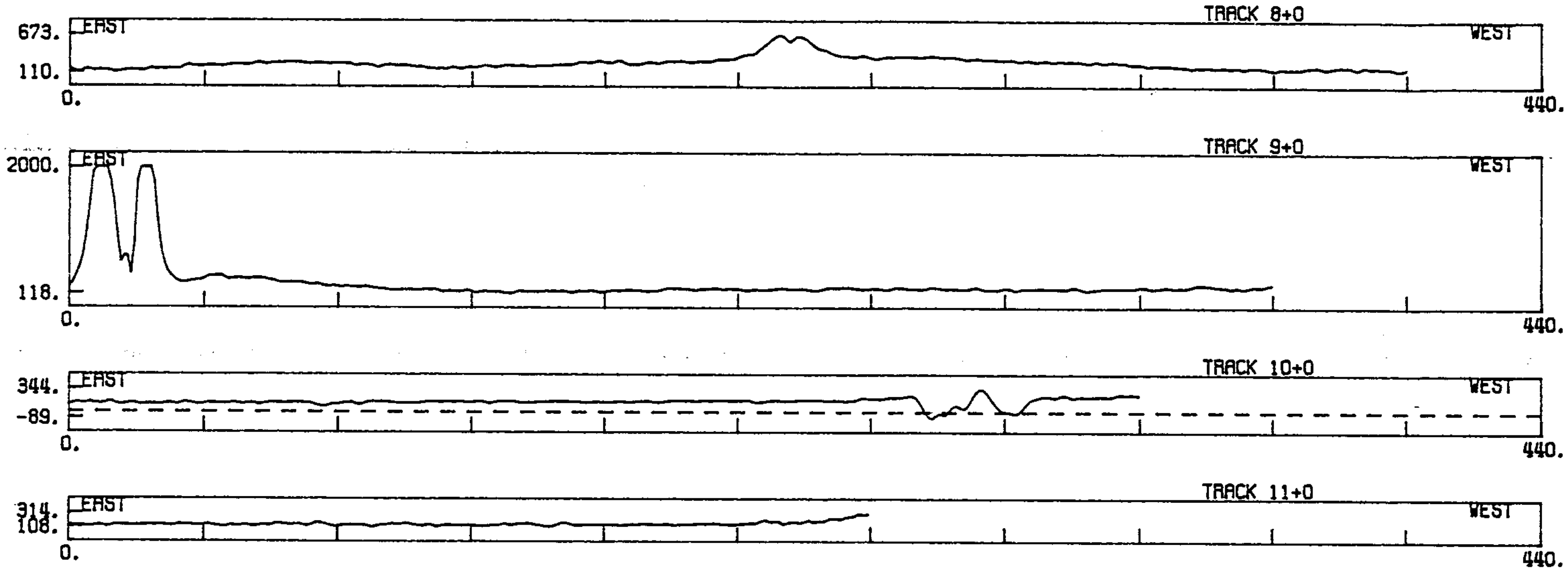



TRACK I+0
SOUTH
NORTH
377.
0.
-622.
0.
400.
TRACK I+10
SOUTH
NORTH
504.
0.
-236.
0.
400.
TRACK I+20
SOUTH
NORTH
688.
0.
-288.
0.
400.
TRACK I+30
SOUTH
NORTH
387.
69.
0.
400.
TRACK J+0
SOUTH
NORTH
329.
50.
0.
400.
TRACK J+10
SOUTH
NORTH
404.
67.
0.
400.
TRACK J+20
SOUTH
NORTH
447.
65.
0.
400.
TRACK J+30
SOUTH
NORTH
572.
66.
0.
400.
TRACK K+0
SOUTH
NORTH
415.
47.
0.
400.

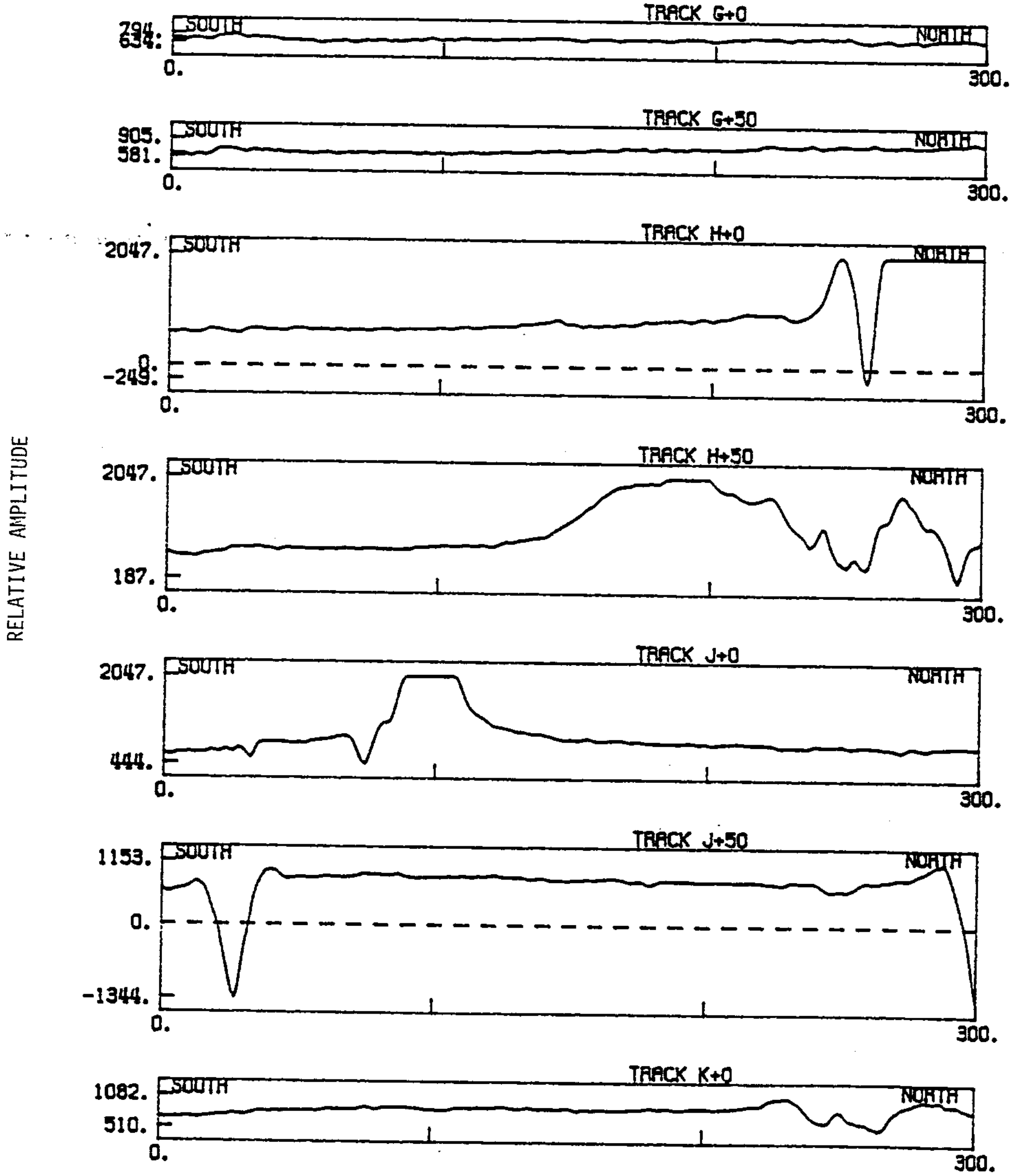

TRACK K+10
294.
42.
SOUTH
NORTH
0.
400.
TRACK K+20
1675.
0.
-2000.
SOUTH
NORTH
0.
400.
TRACK K+30
1279.
0.
-2000.
SOUTH
NORTH
0.
400.
TRACK L+0
156.
35.
SOUTH
NORTH
0.
400.
TRACK F+0
656.
0.
-1916.
SOUTH
NORTH
0.
400.


TRACK 1+0
EAST
WEST
262.
53.
0.
440.
TRACK 2+0
EAST
WEST
189.
83.
0.
440.
TRACK 3+0
EAST
WEST
1670.
70.
0.
440.
TRACK 4+0
EAST
WEST
252.
87.
0.
440.
TRACK 5+0
EAST
WEST
490.
70.
0.
440.
TRACK 6+0
EAST
WEST
570.
0.
-2000.
0.
440.
TRACK 7+0
EAST
WEST
818.
0.
-2000.
0.
440.

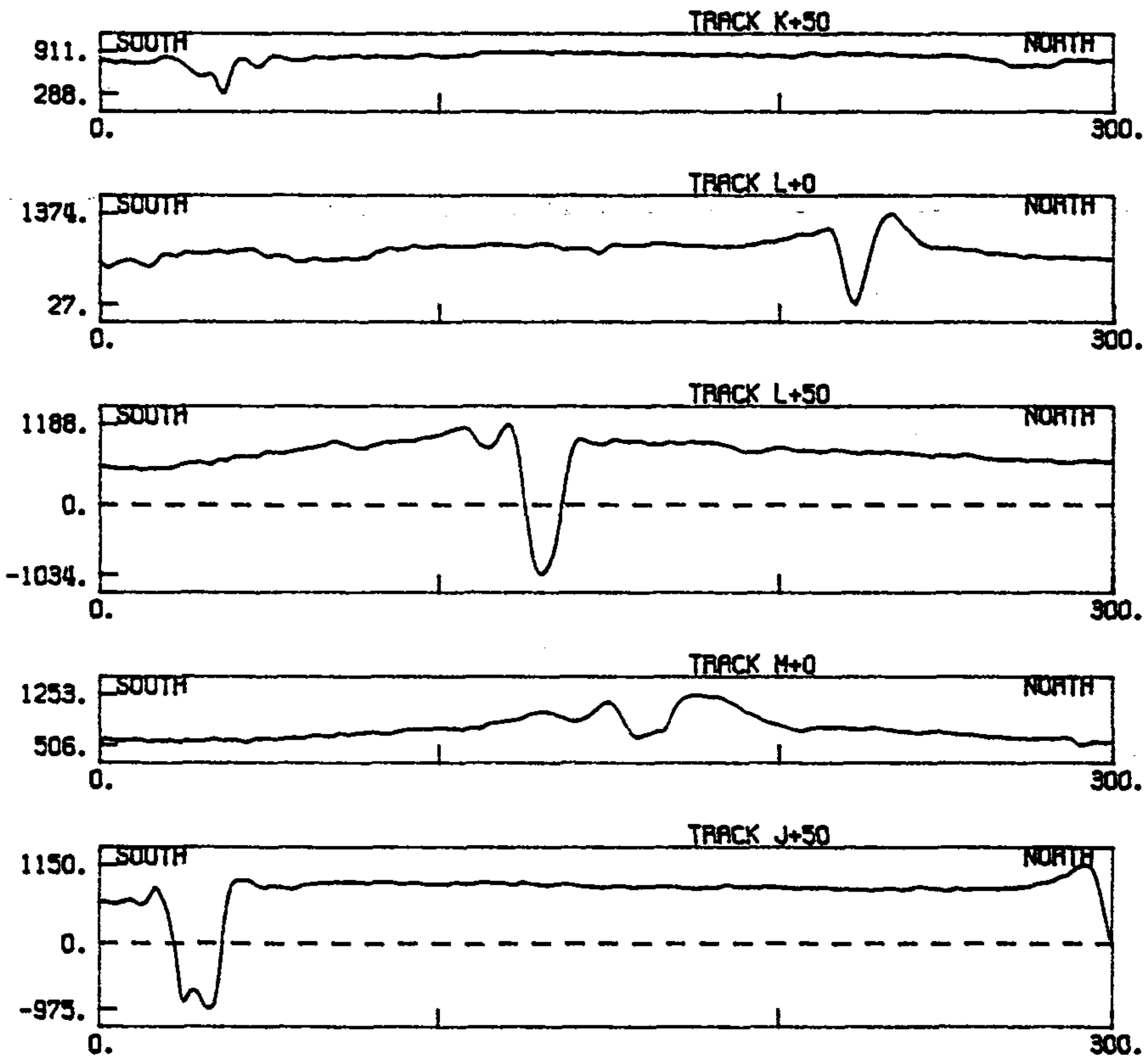
EM31 PROFILES, SITE 1100-3



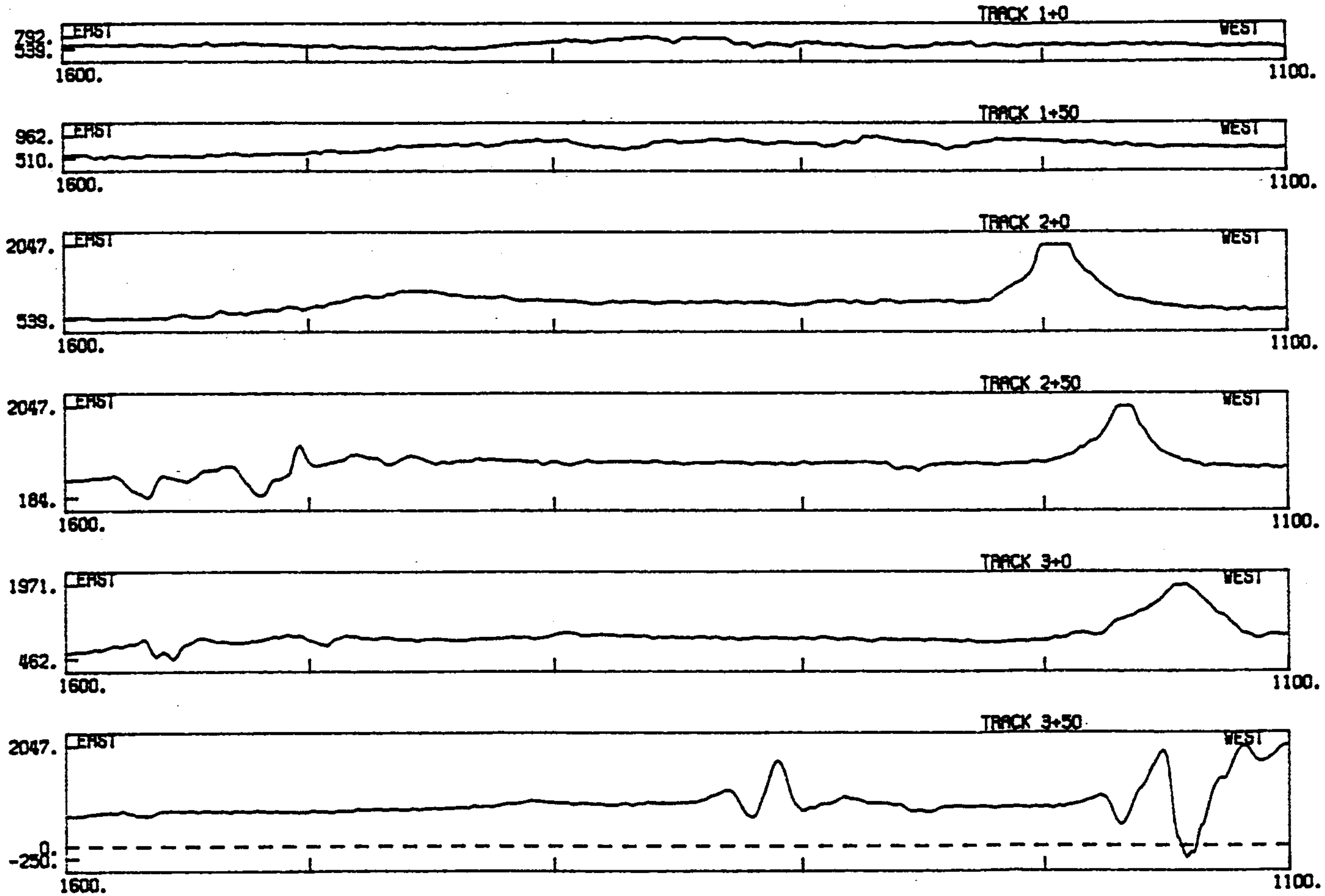
EM31 PROFILES, HORN RAPIDS LANDFILL



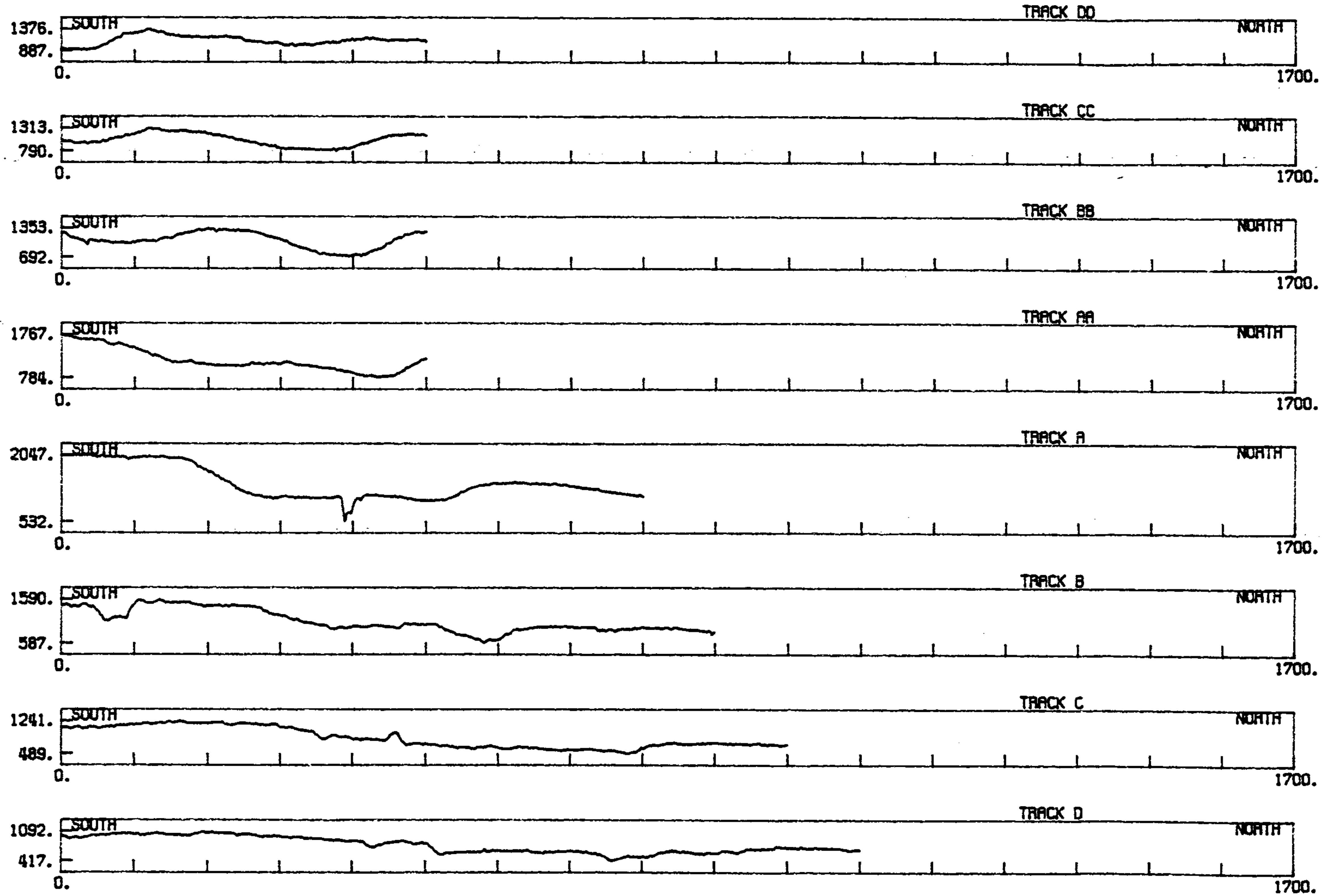
EM31 PROFILES, HORN RAPIDS LANDFILL PAGE 2

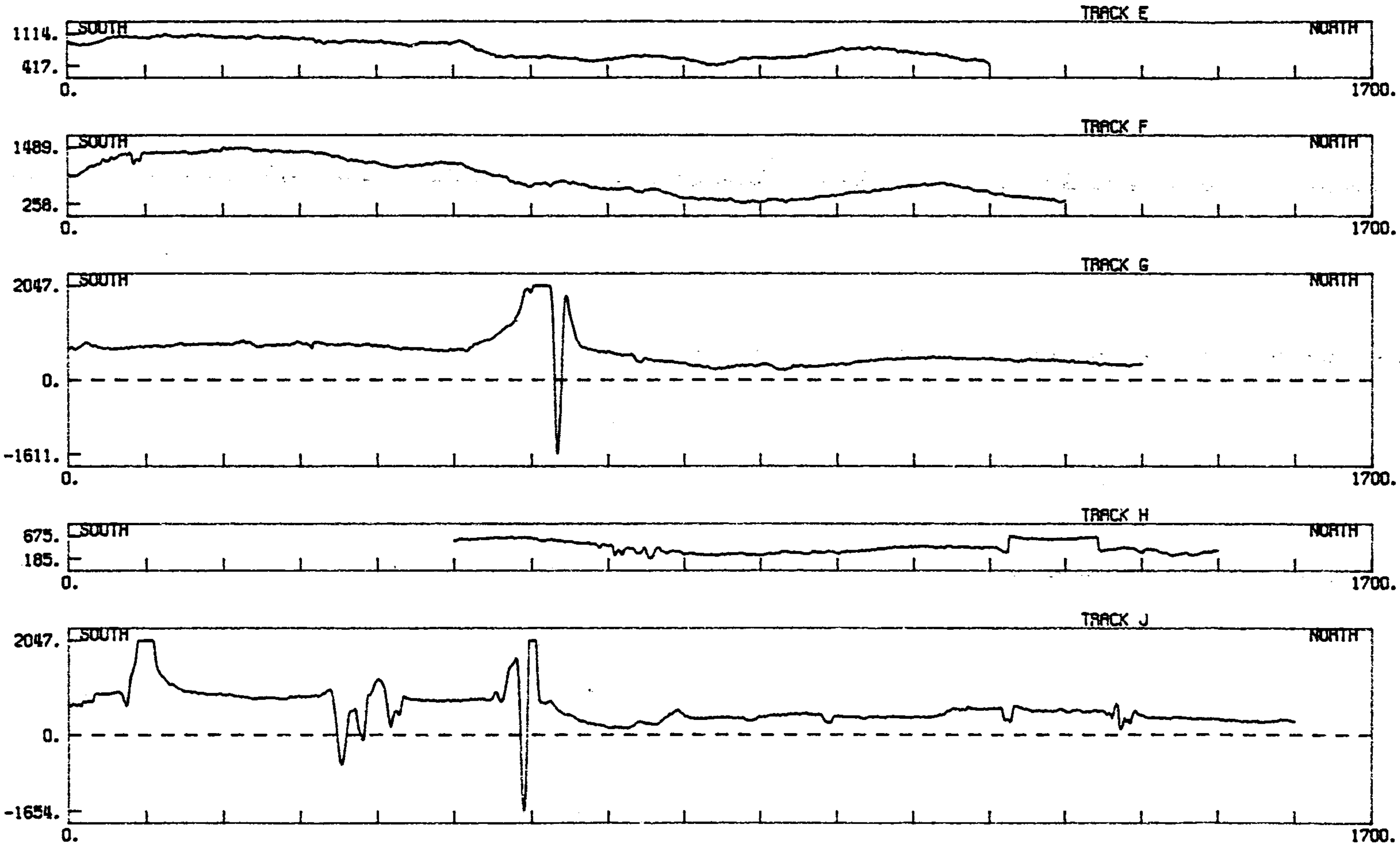


EM31 PROFILES, HORN RAPIDS LANDFILL

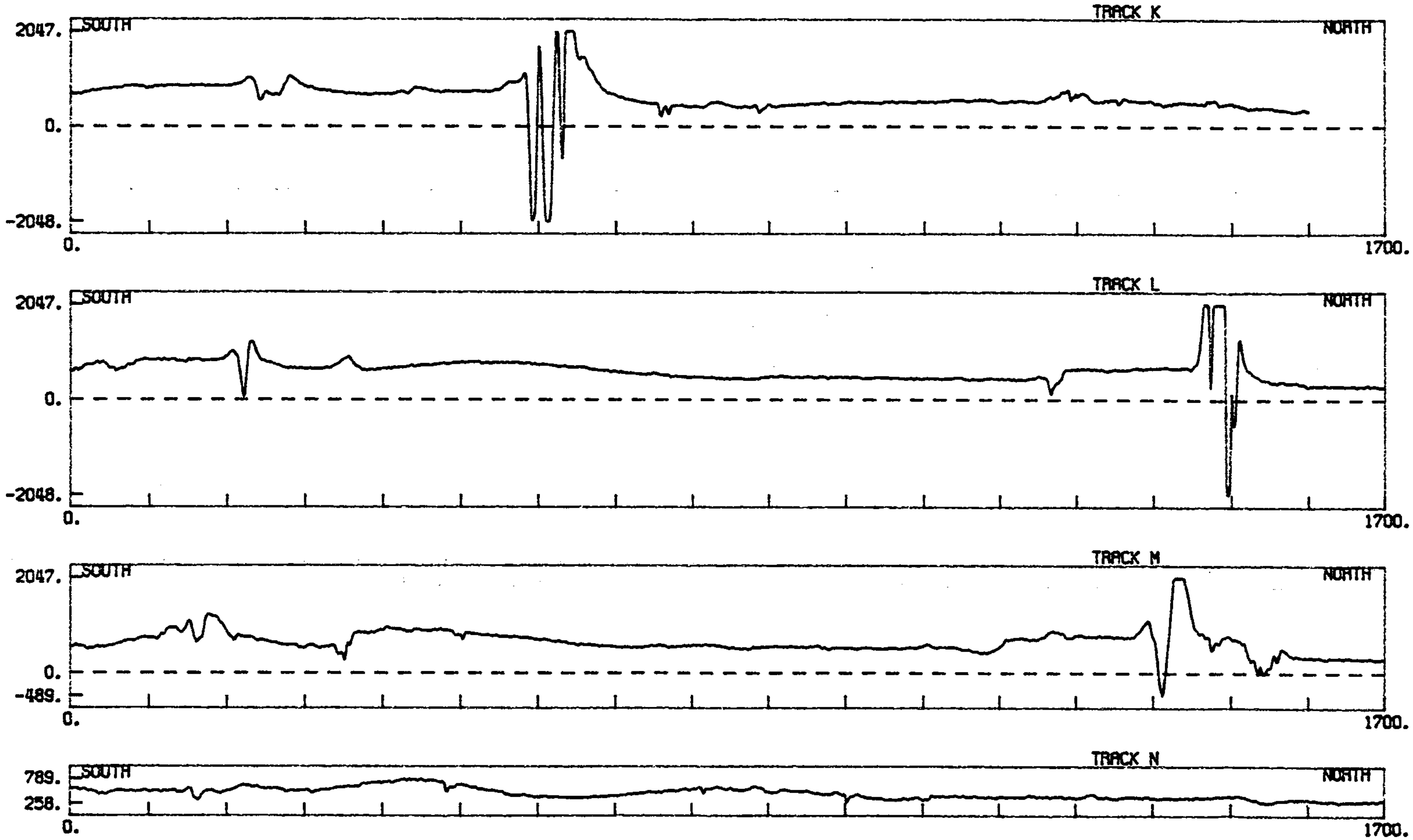


EM31 PROFILES, HORN RAPIDS LANDFILL

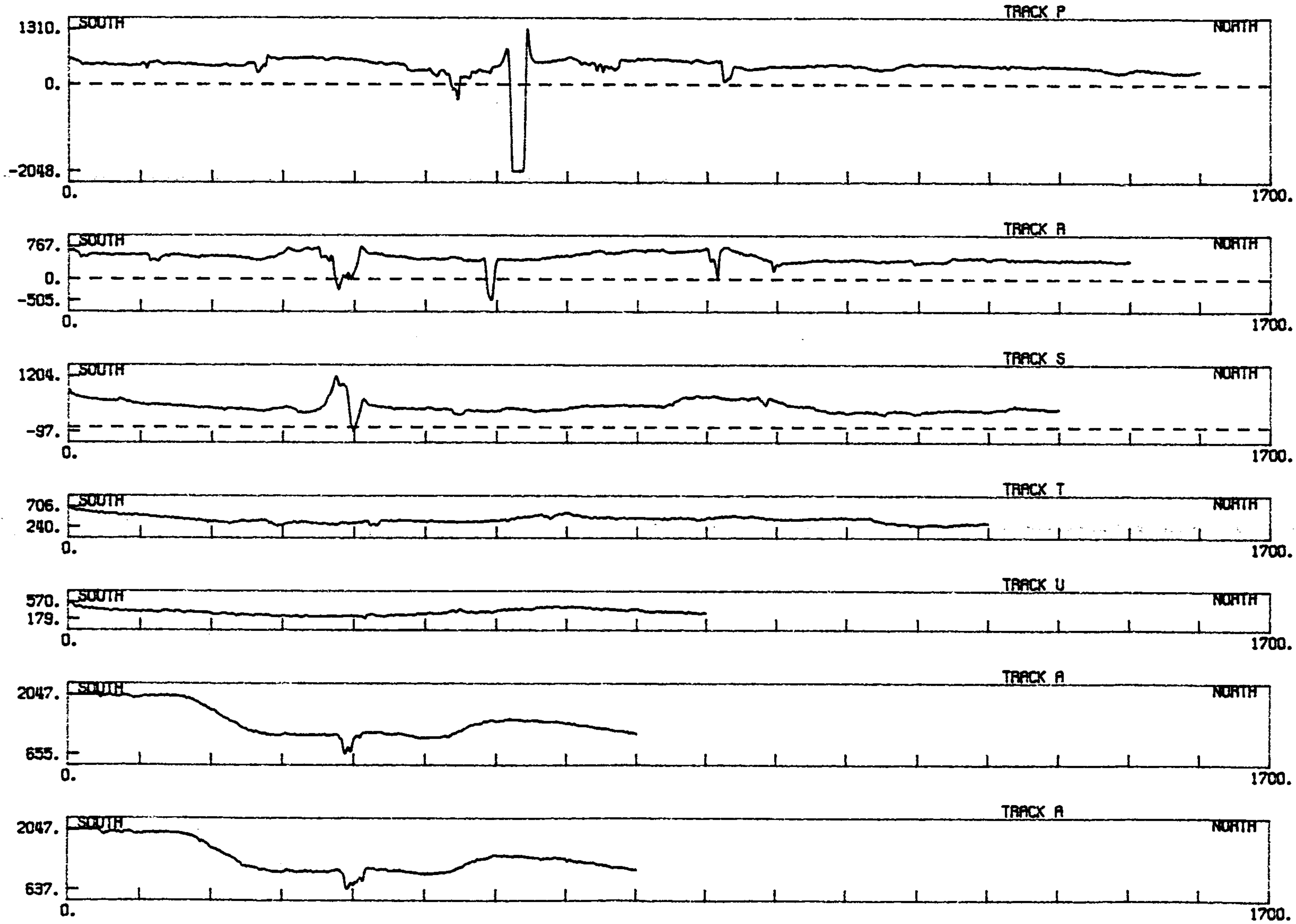



TRACK E
SOUTH
NORTH
1114.
417.
0.
1700.
TRACK F
SOUTH
NORTH
1489.
258.
0.
1700.
TRACK G
SOUTH
NORTH
2047.
0.
-1611.
0.
1700.
TRACK H
SOUTH
NORTH
675.
185.
0.
1700.
TRACK J
SOUTH
NORTH
2047.
0.
-1654.
0.
1700.

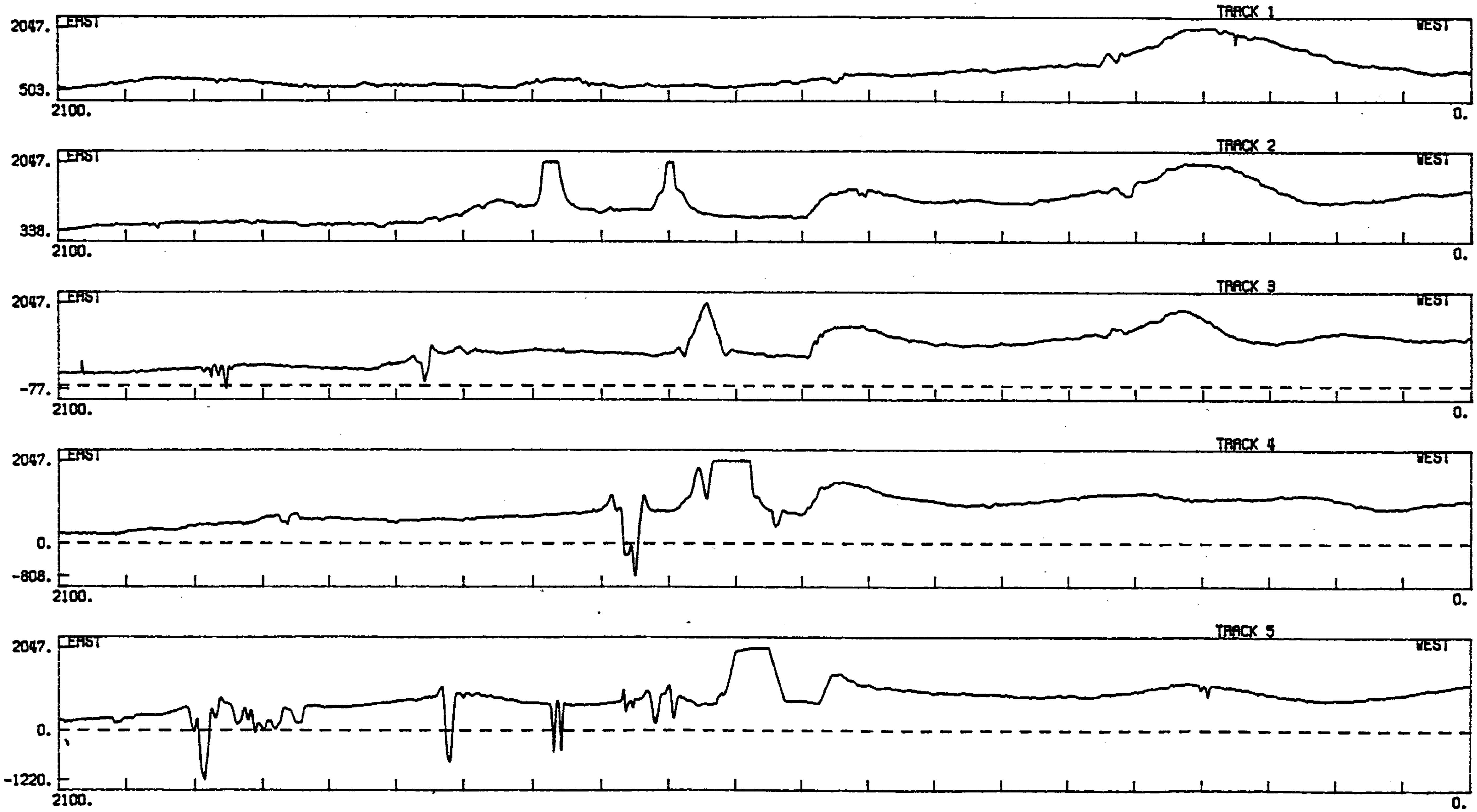
EM31 PROFILES, HORN RAPIDS LANDFILL



EM31 PROFILES, HORN RAPIDS LANDFILL




TRACK S
1272.
SOUTH
NORTH
-200.
0.
1700.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2100.
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TRACK 2
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WEST
338.
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TRACK 3
2047.
EAST
WEST
-77.
2100.
0.
TRACK 4
2047.
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-808.
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WEST
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-1220.
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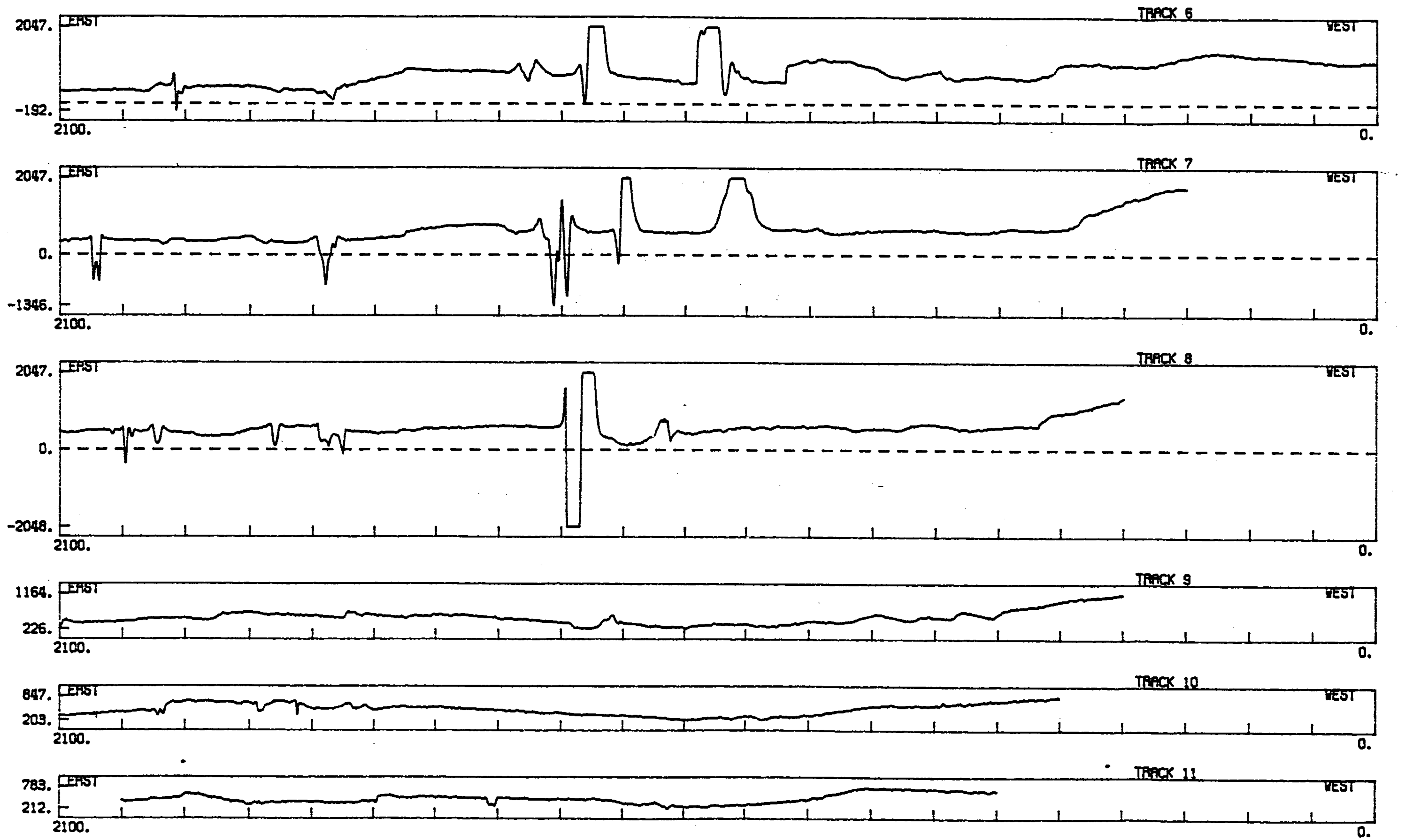
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-1346.
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EAST
WEST
TRACK 8
2047.
0.
-2048.
2100.
0.
EAST
WEST
TRACK 9
1164.
226.
2100.
0.
EAST
WEST
TRACK 10
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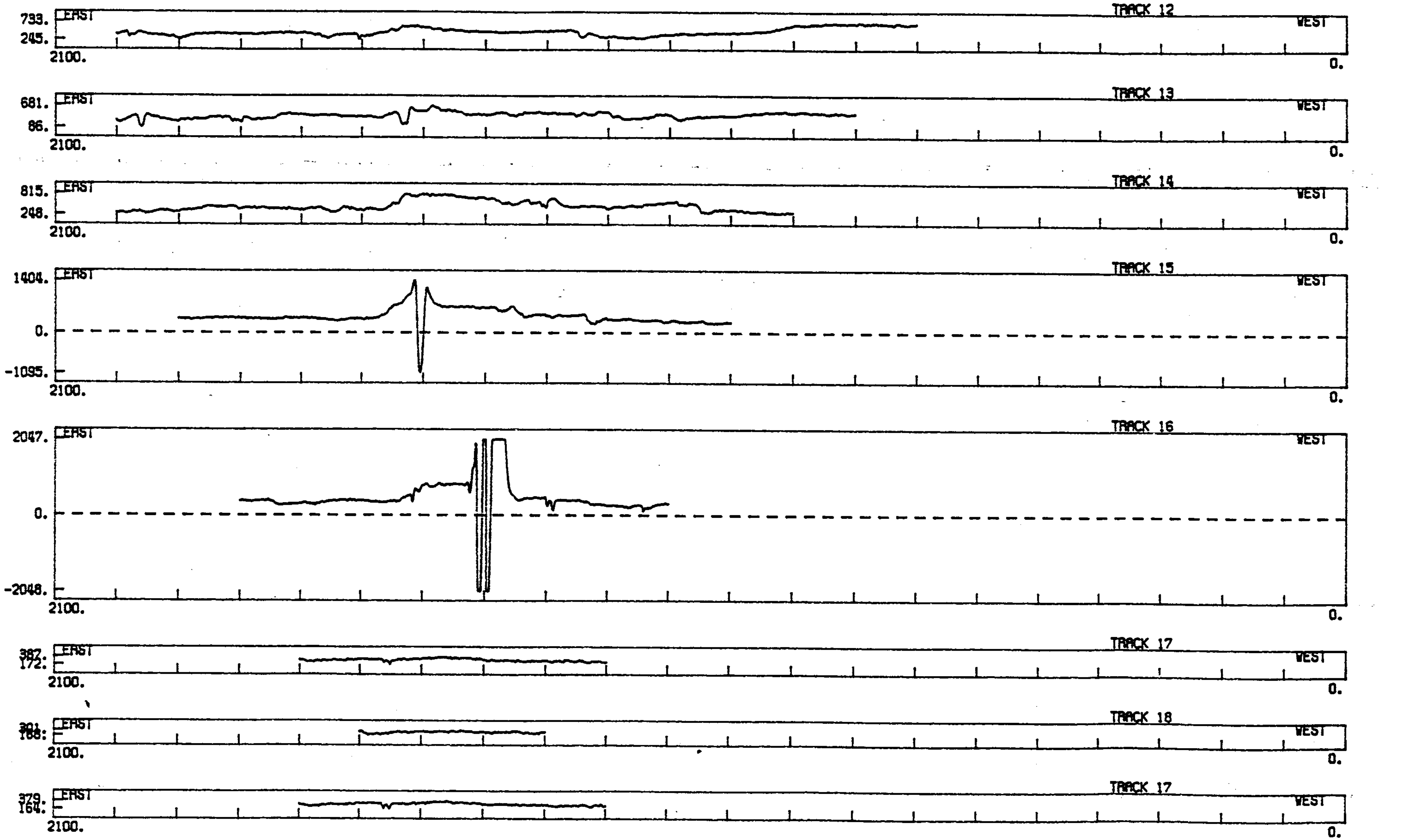
EAST
WEST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815.
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EAST
WEST
2100.
0.
TRACK 15
1404.
0.
-1095.
EAST
WEST
2100.
0.
TRACK 16
2047.
0.
-2048.
EAST
WEST
2100.
0.
TRACK 17
382.
172.
EAST
WEST
2100.
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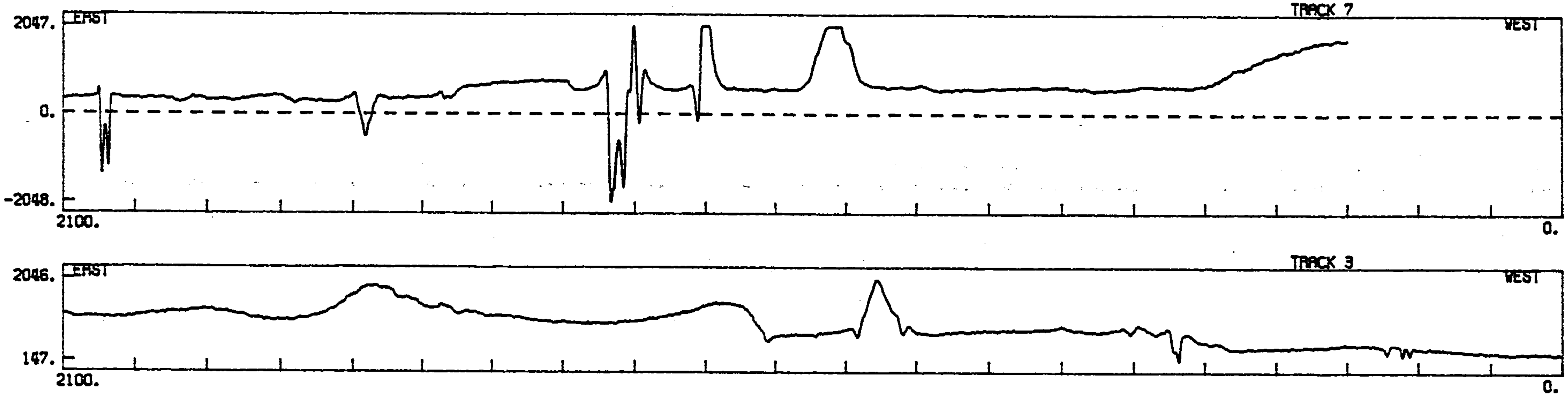
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WEST
2047.
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-2048.
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TRACK 3
EAST
WEST
2046.
147.
2100.
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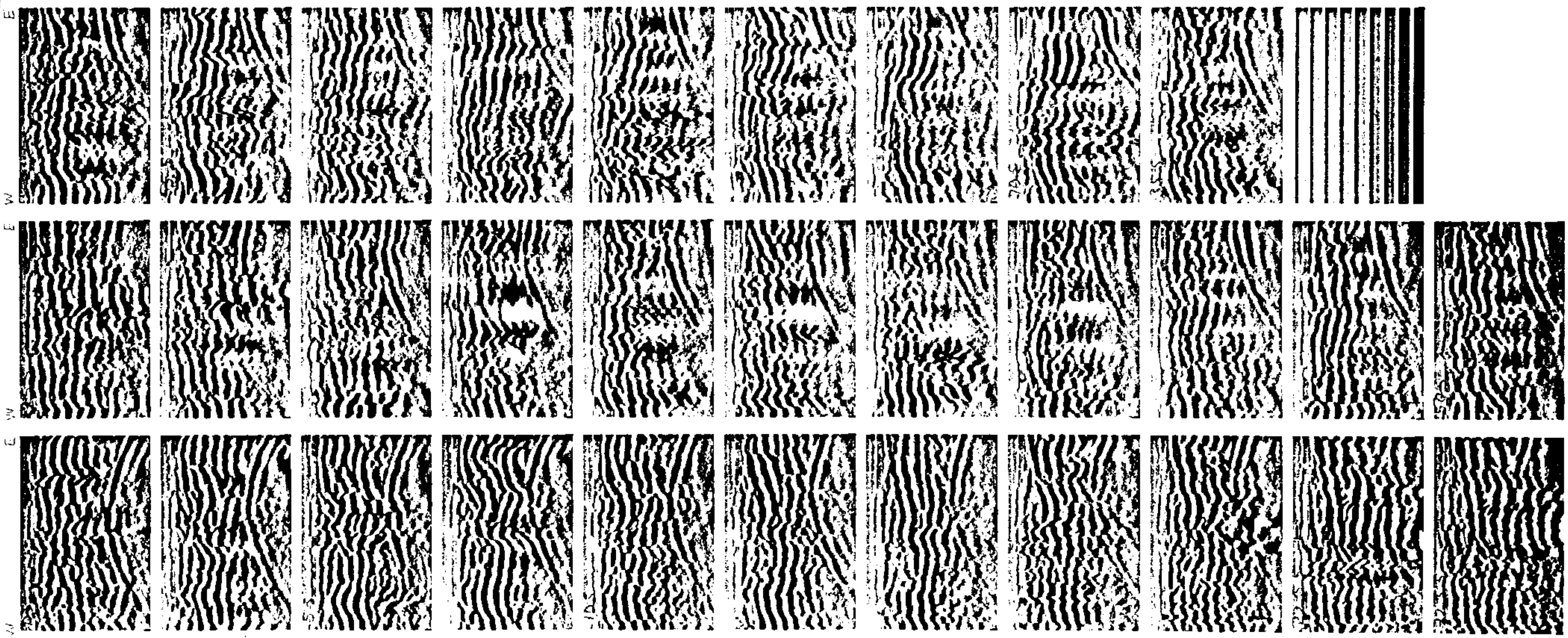
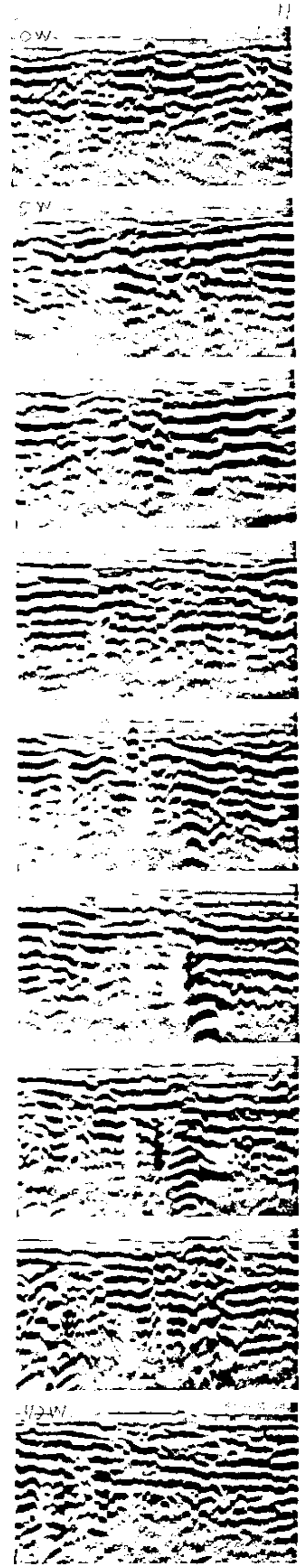
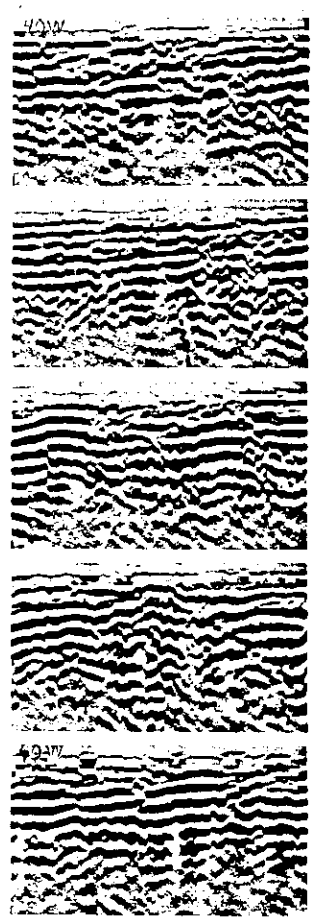
GPR PROFILES

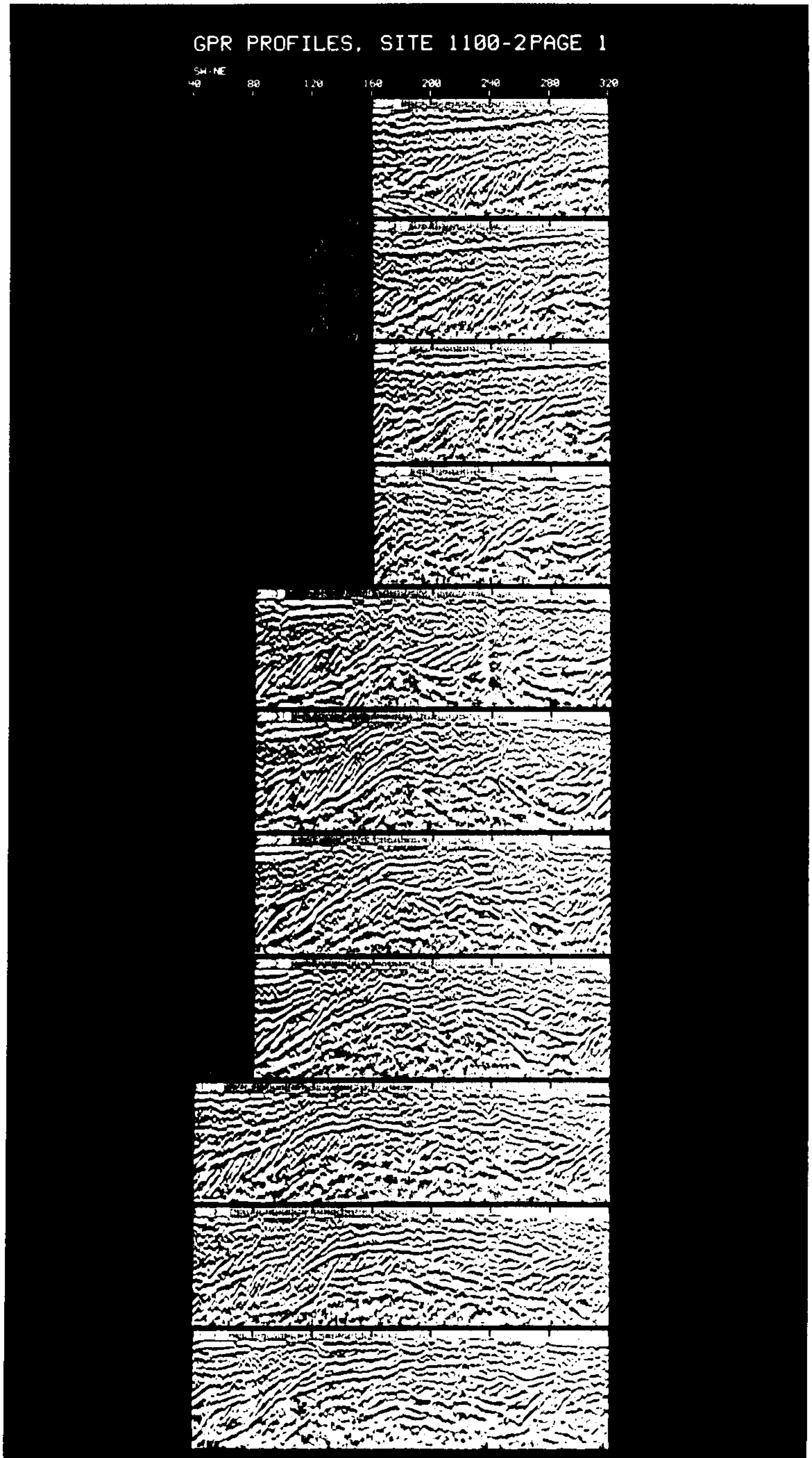


GPR PROFILES, BATTERY ACID PIT PAGE 2



GPR PROFILES BATTERY ACID PIT PAGE 3




GPR PROFILES. SITE 1100-2PAGE 1
SW-NE
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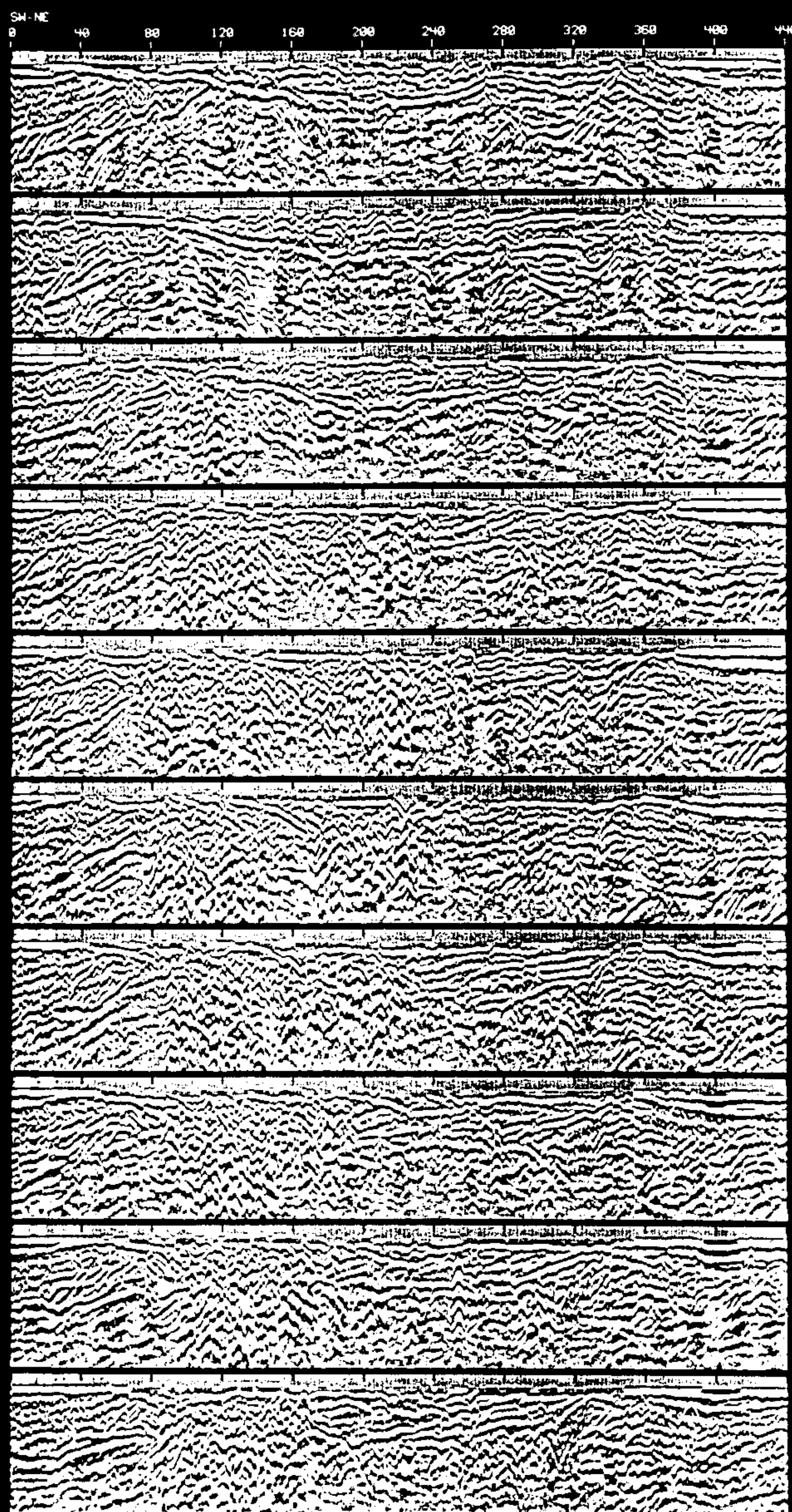
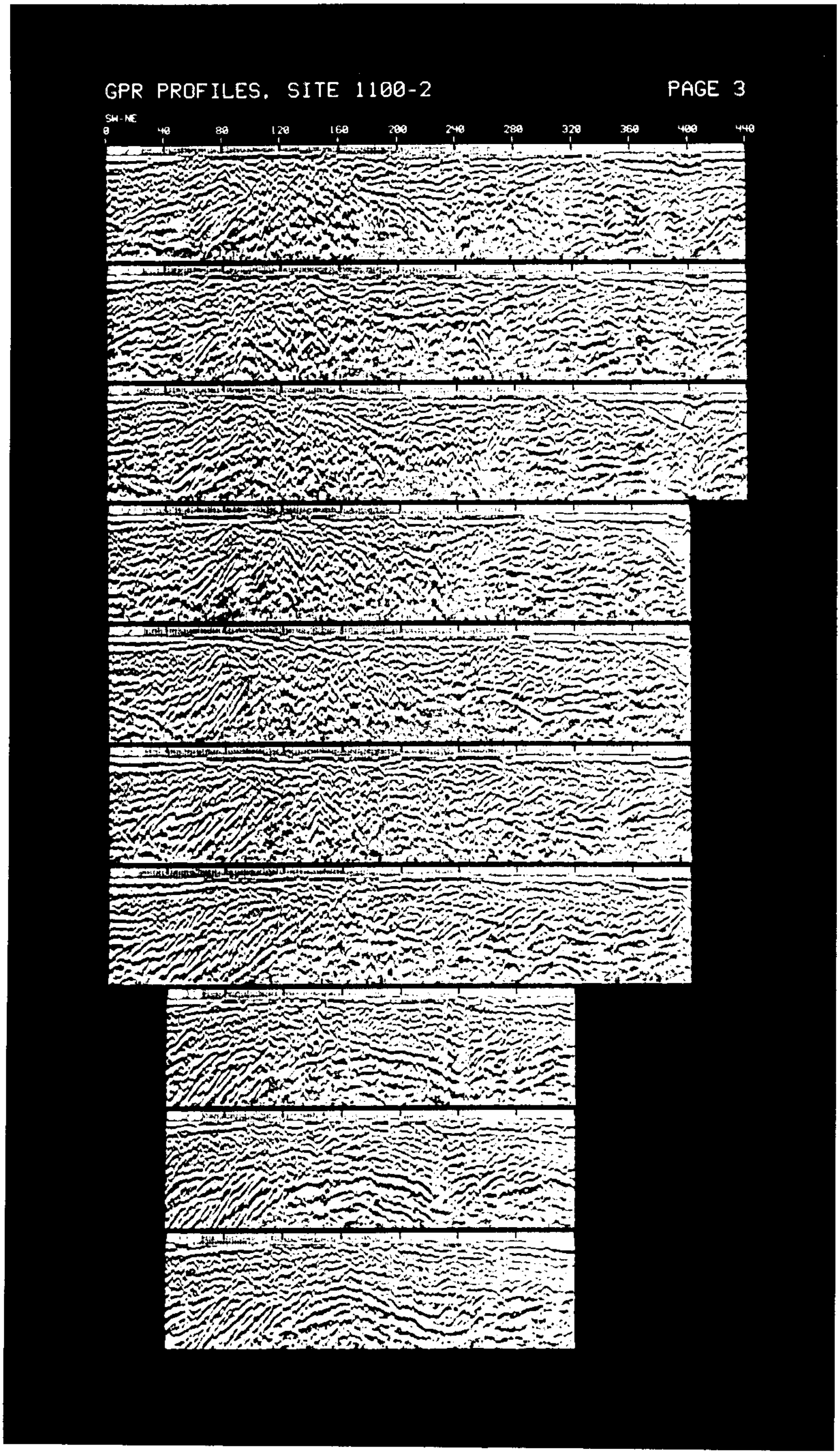
320

GPR PROFILES, SITE 1100-2




GPR PROFILES. SITE 1100-2
PAGE 3
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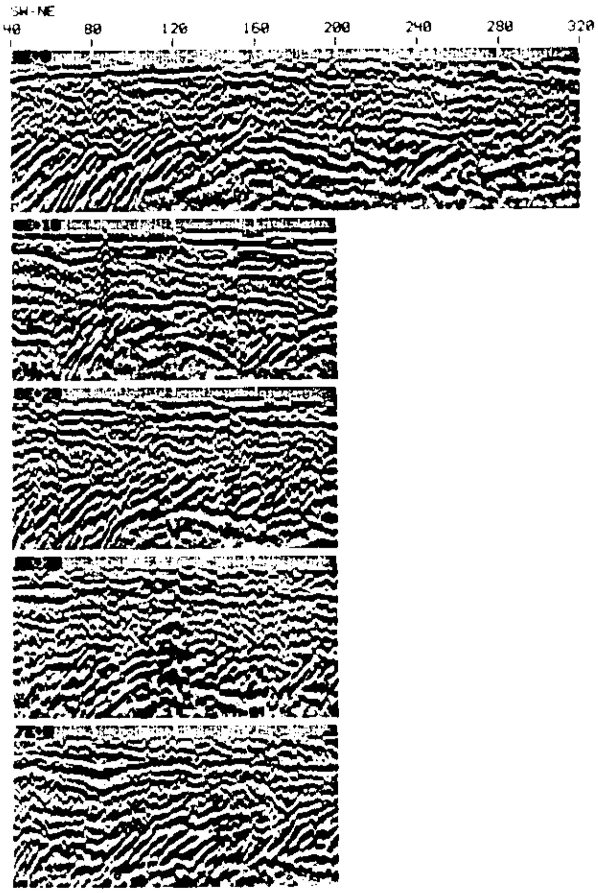
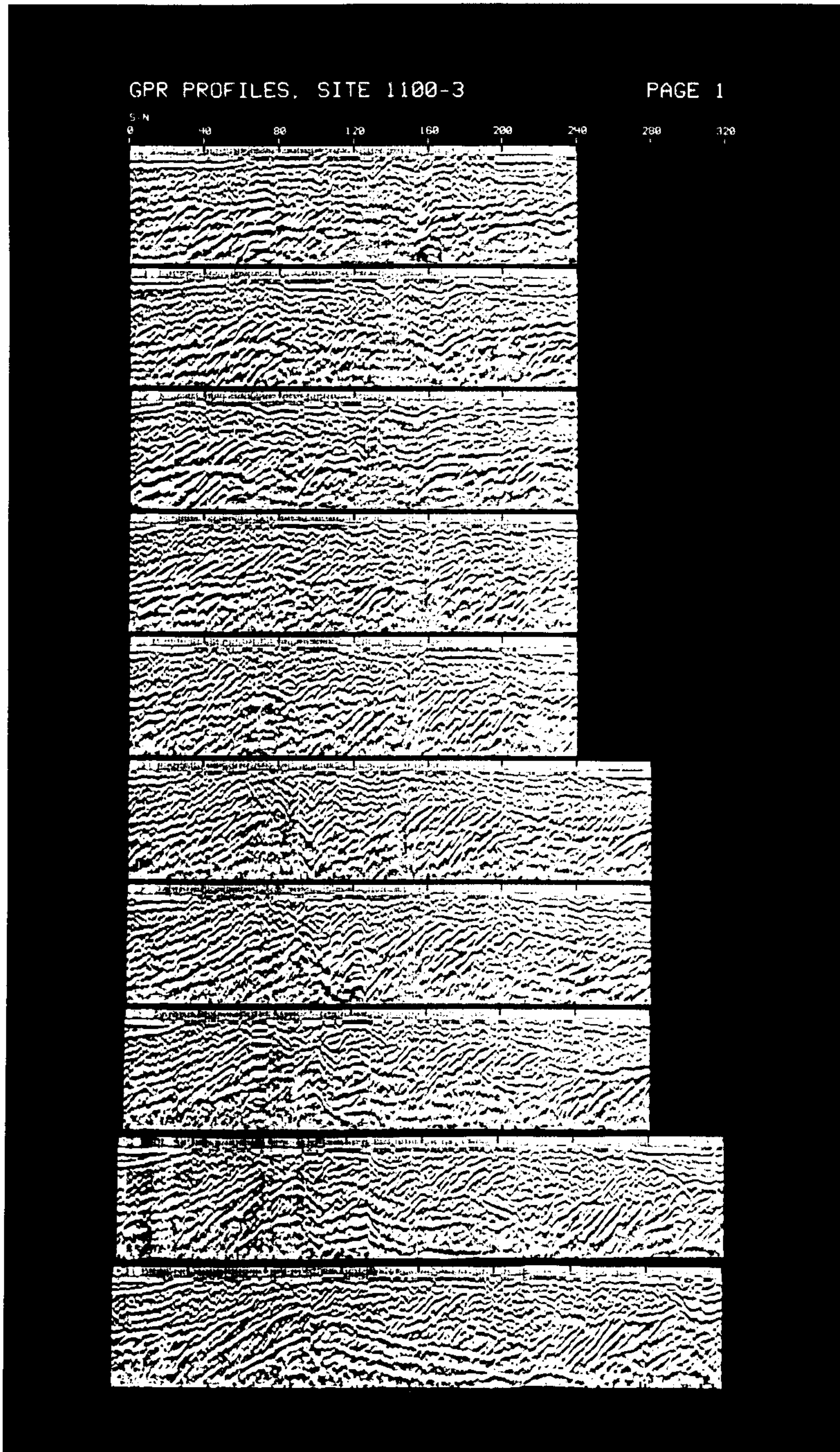
GPR PROFILES, SITE 1100-2 PAGE 4




GPR PROFILES, SITE 1100-3
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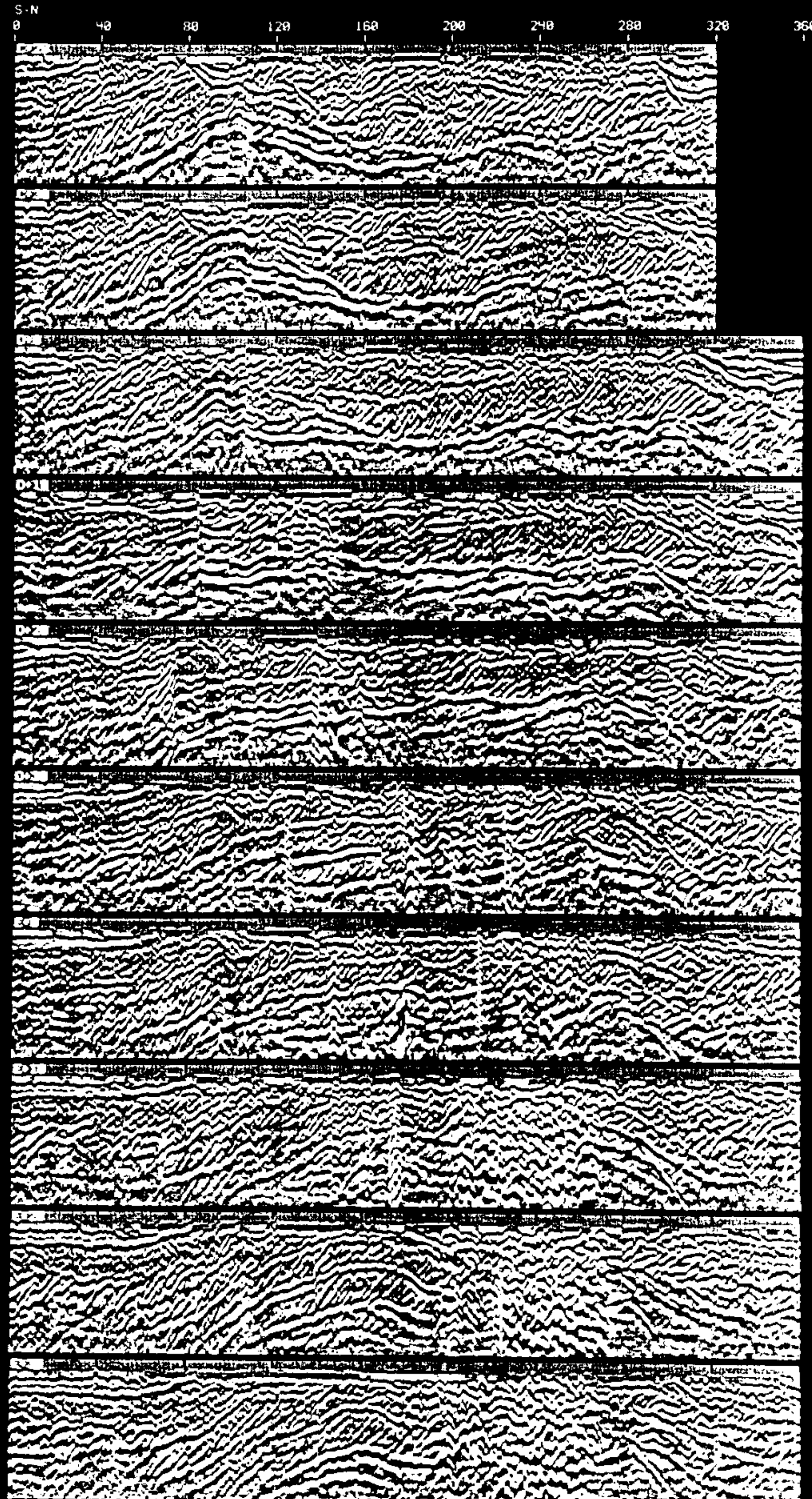
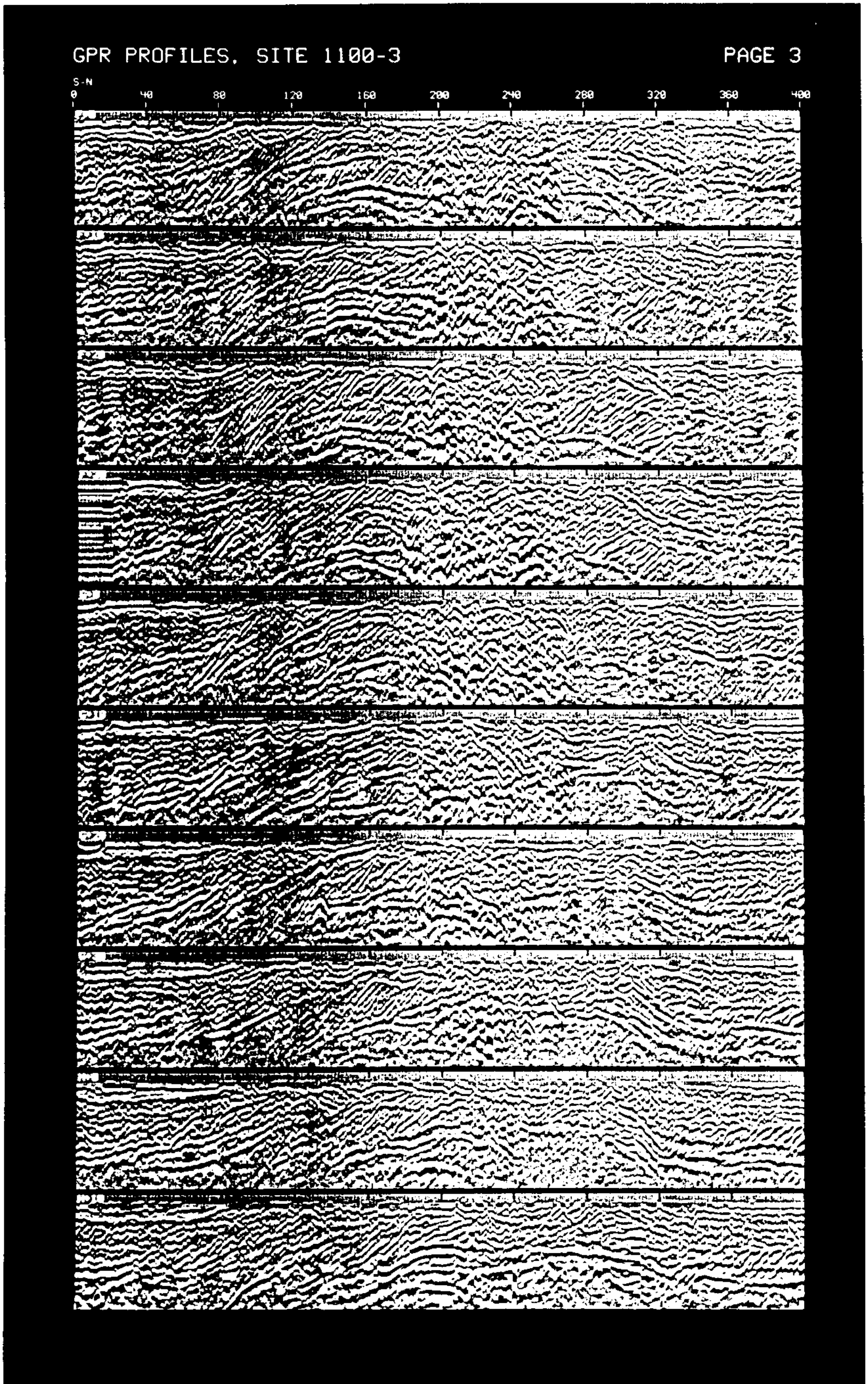
GPR PROFILES, SITE 1100-3




GPR PROFILES, SITE 1100-3
PAGE 3
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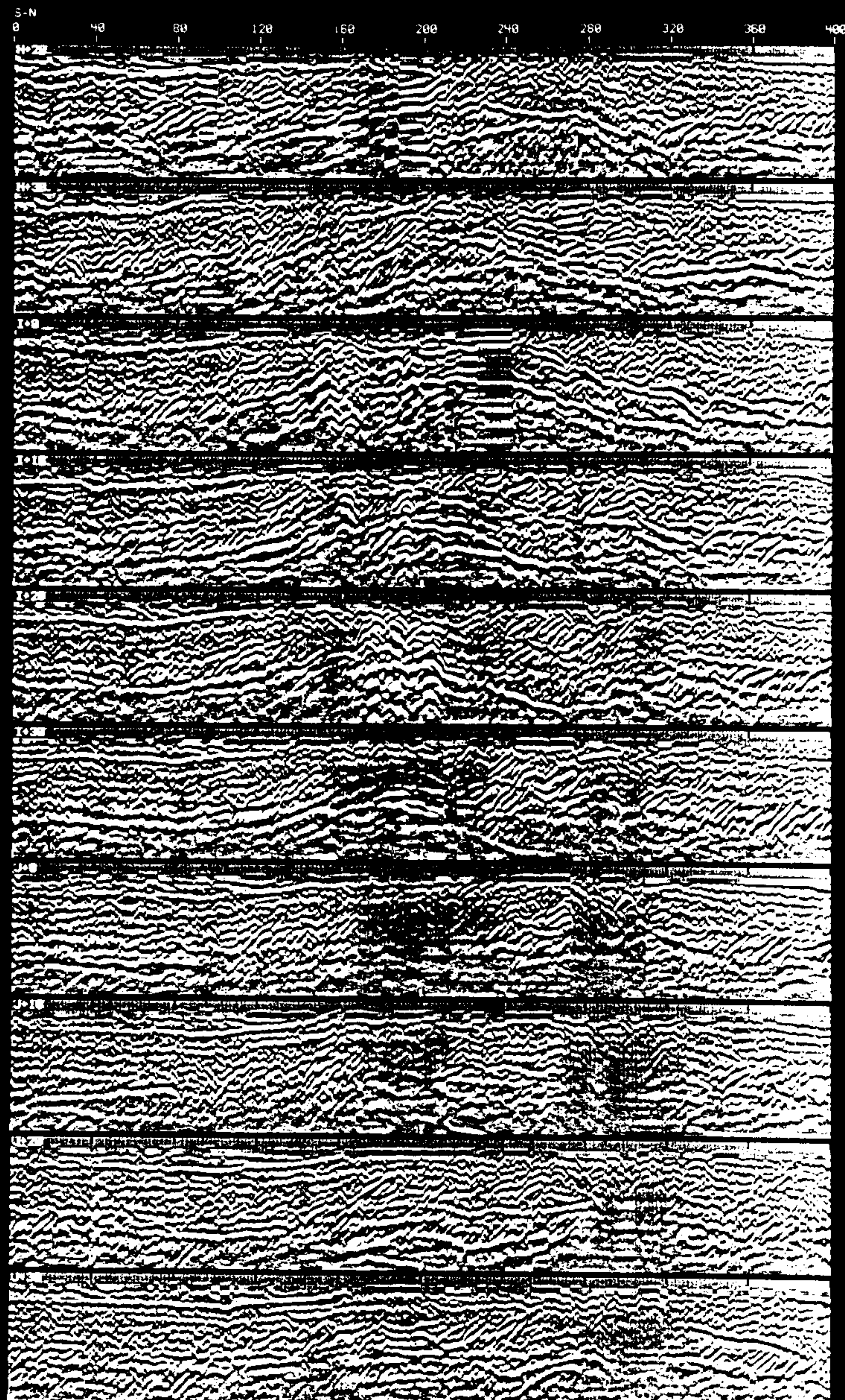
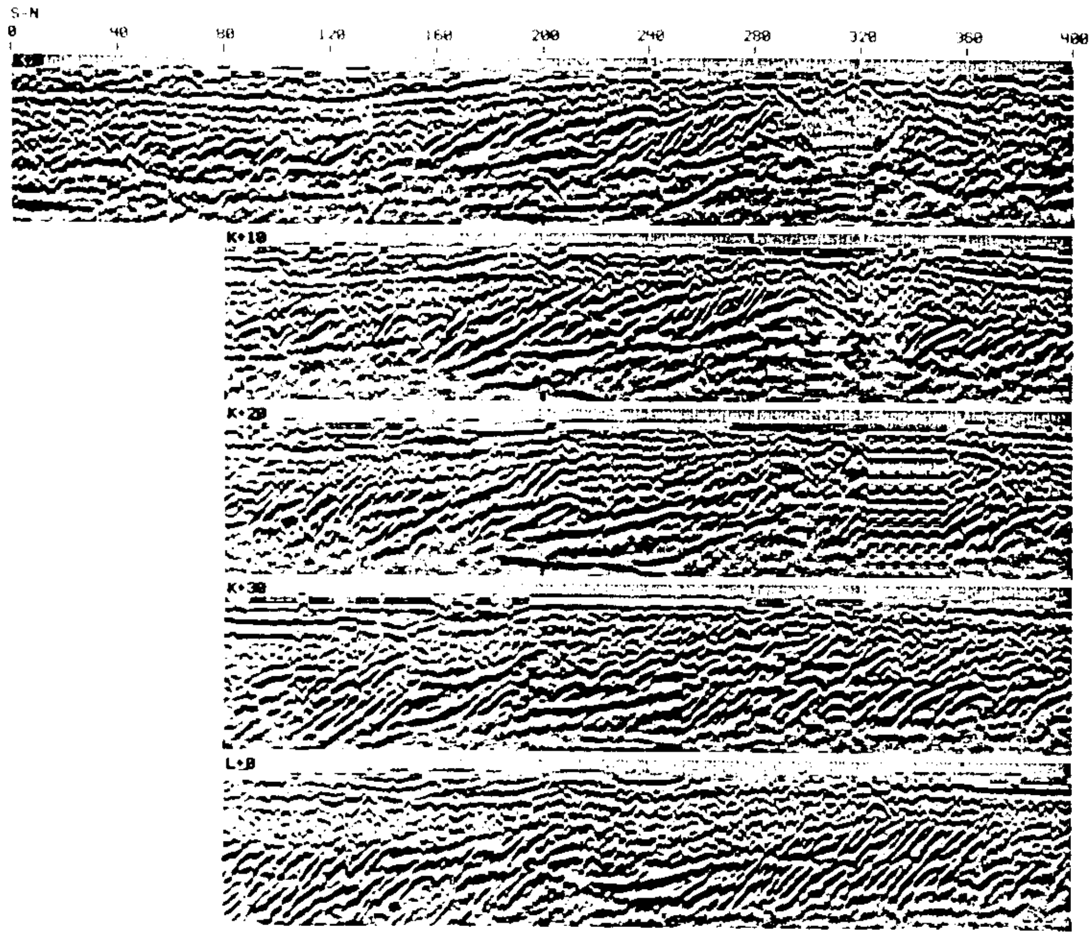
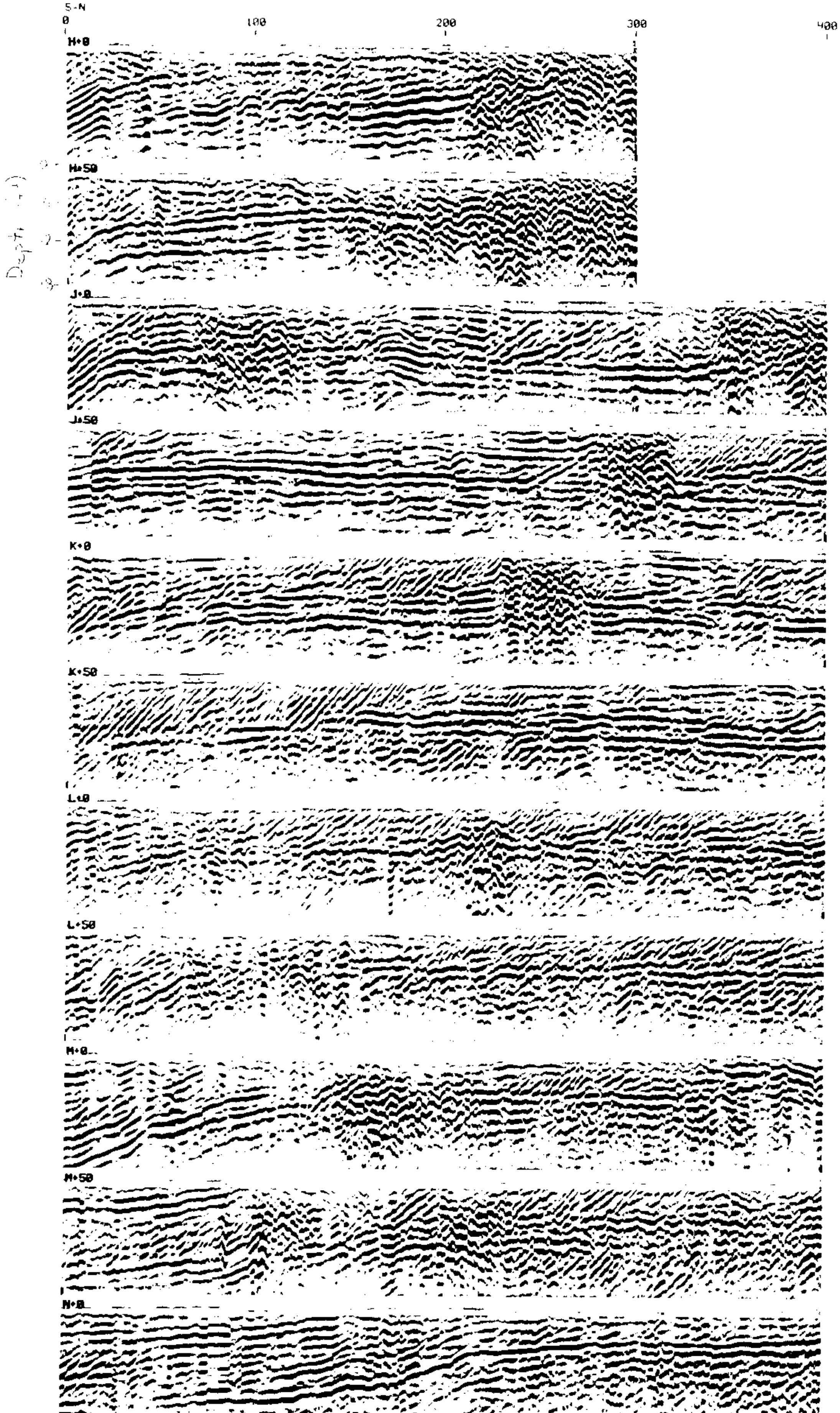
GPR PROFILES, SITE 1100-3



GPR PROFILES, SITE 1100-3



GPR PROFILES, HORN RAPIDS LANDFILL



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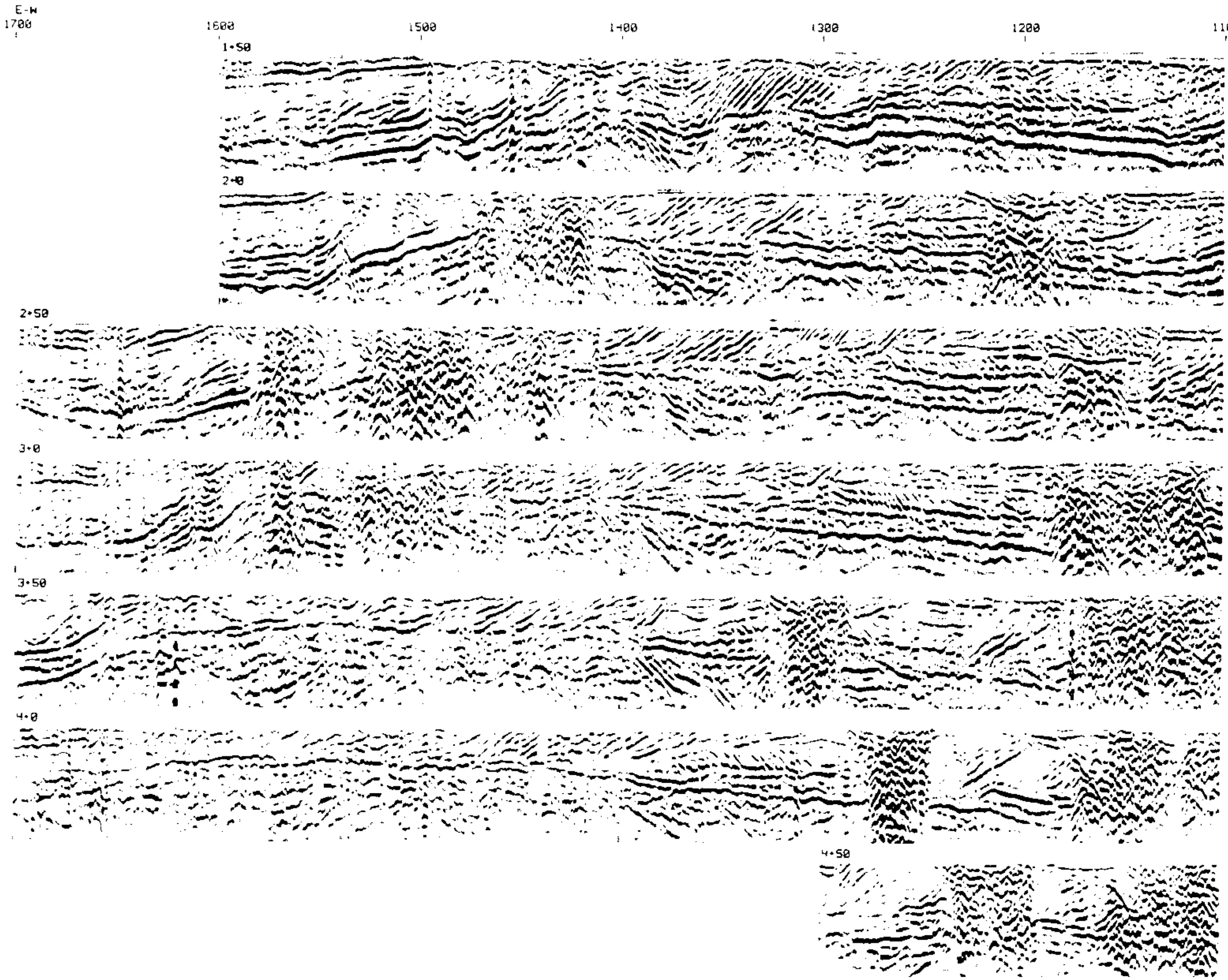

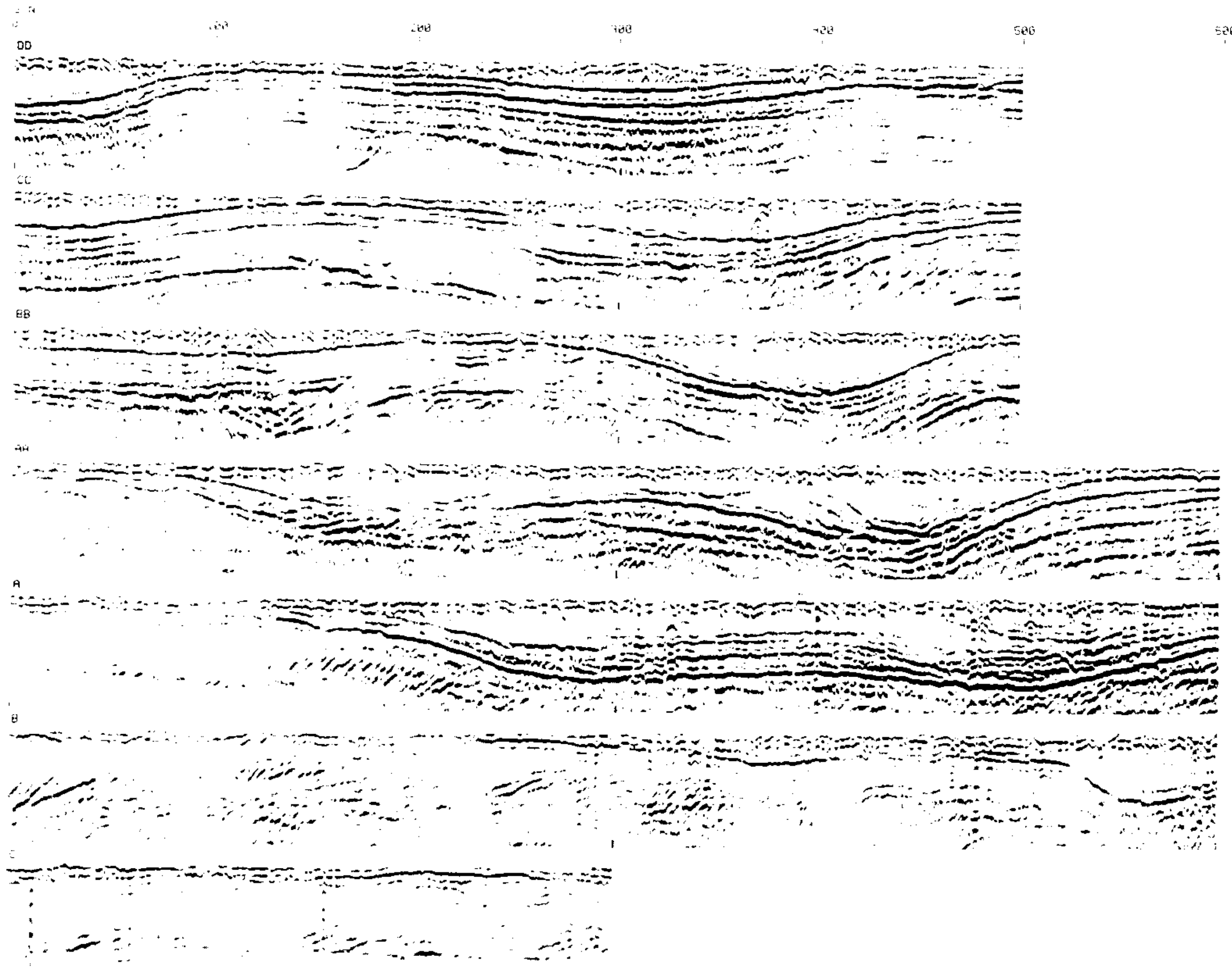
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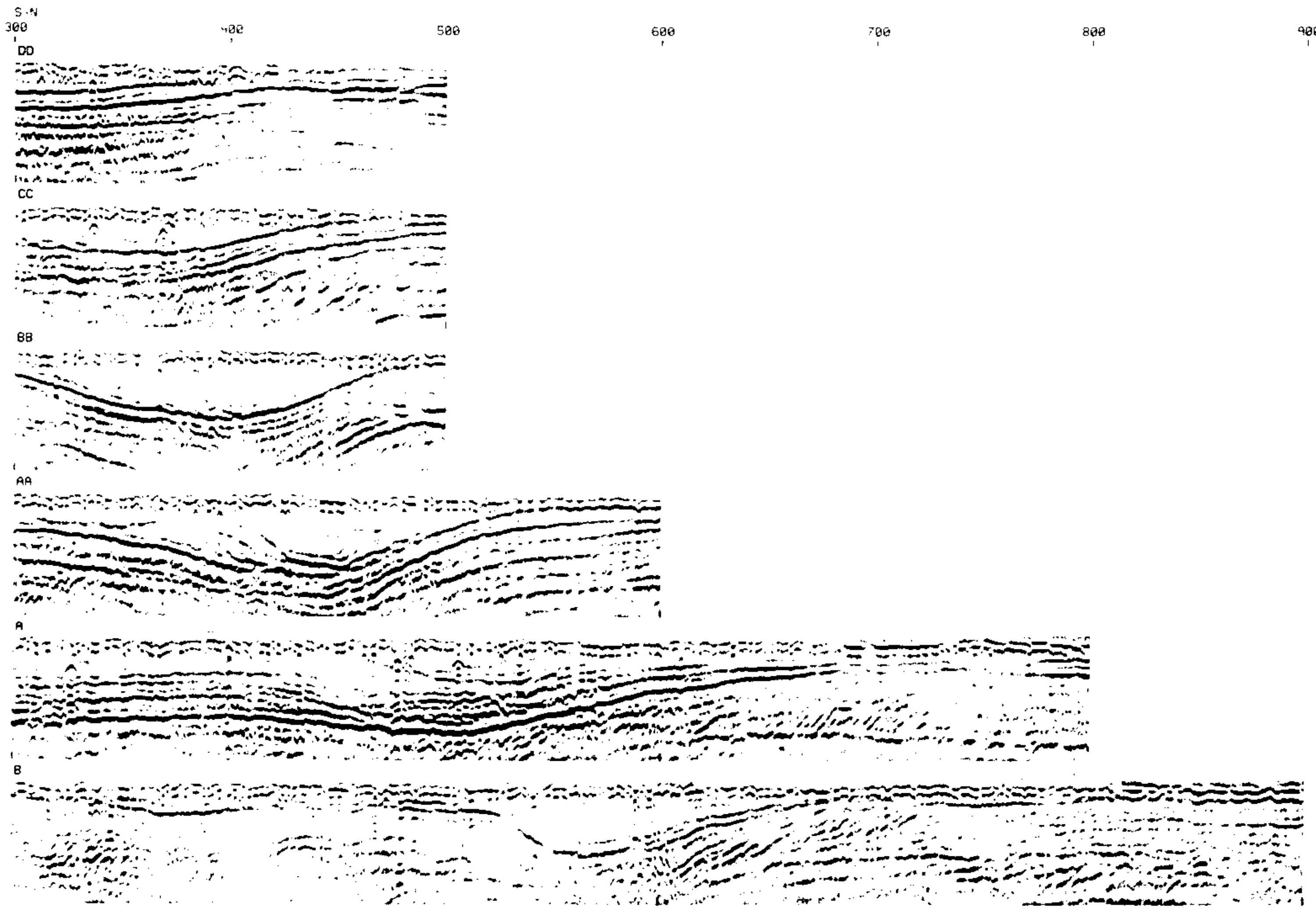
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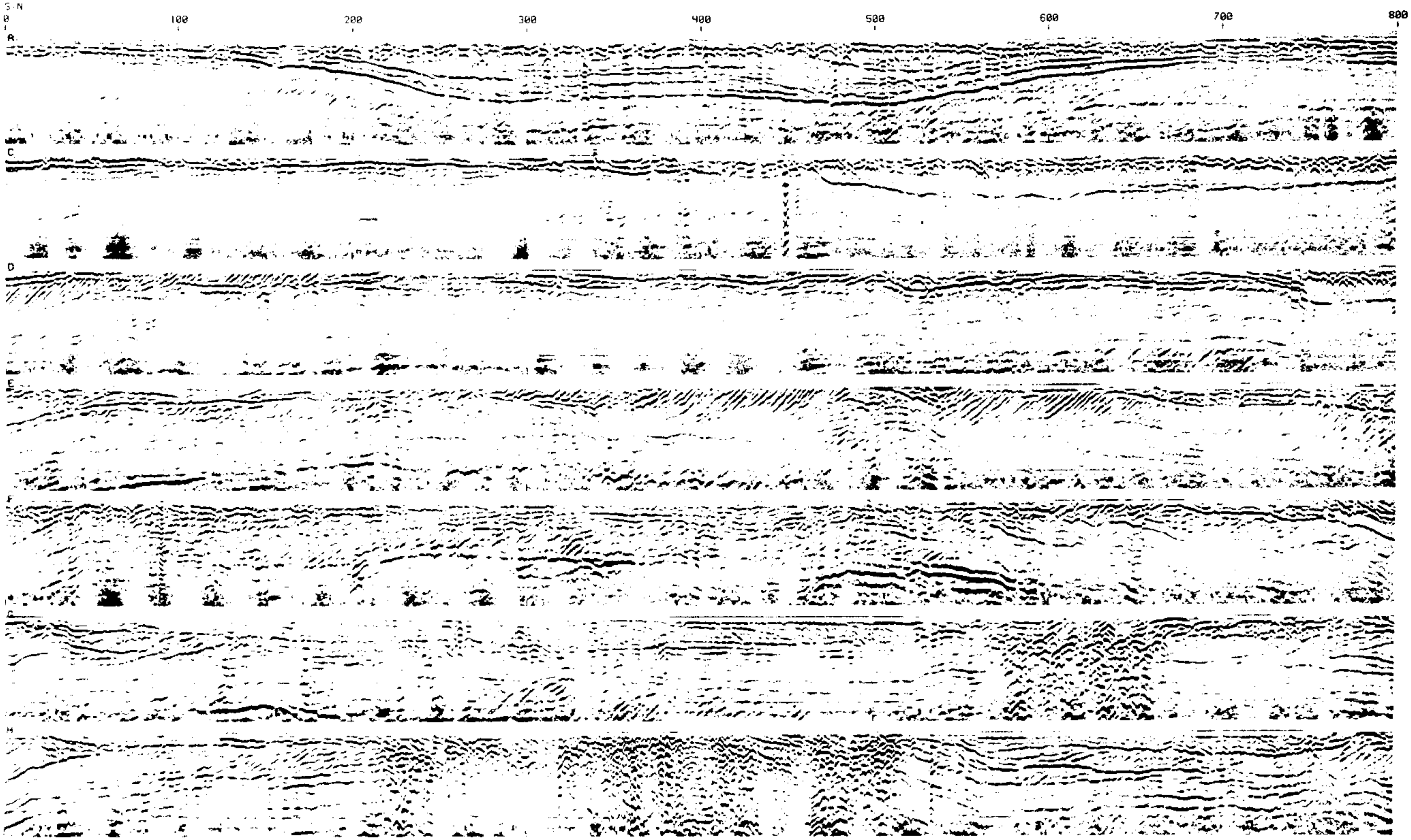
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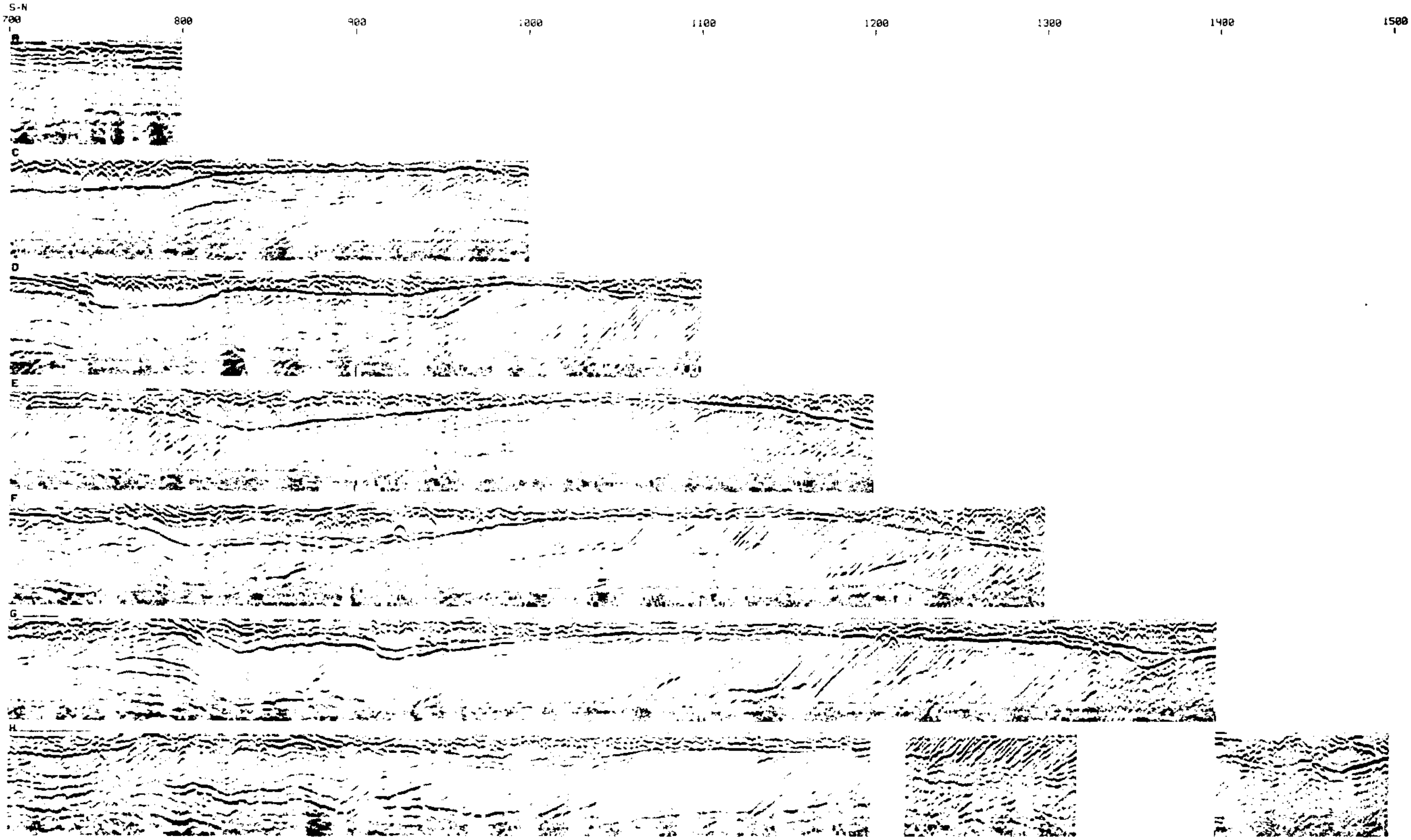
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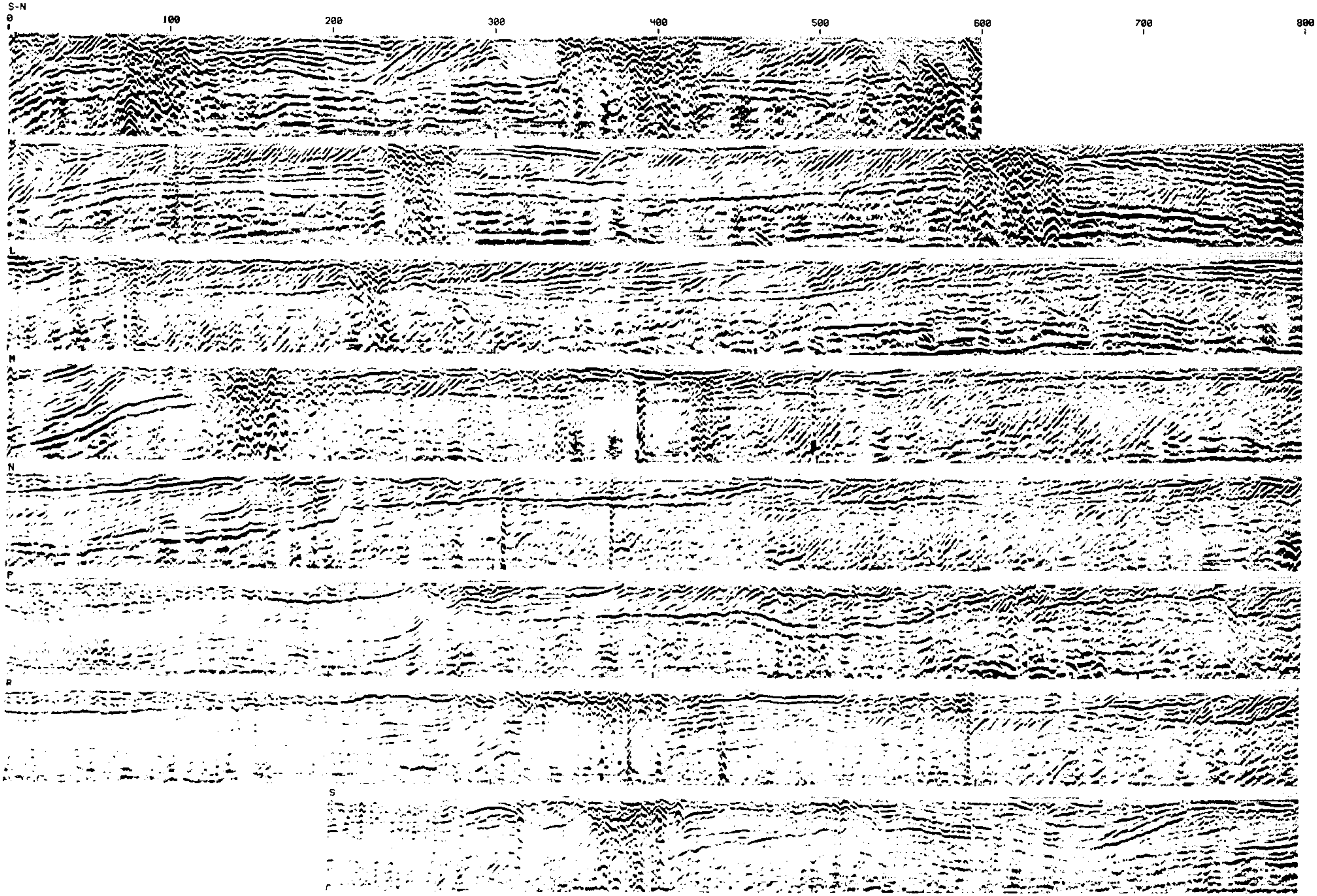
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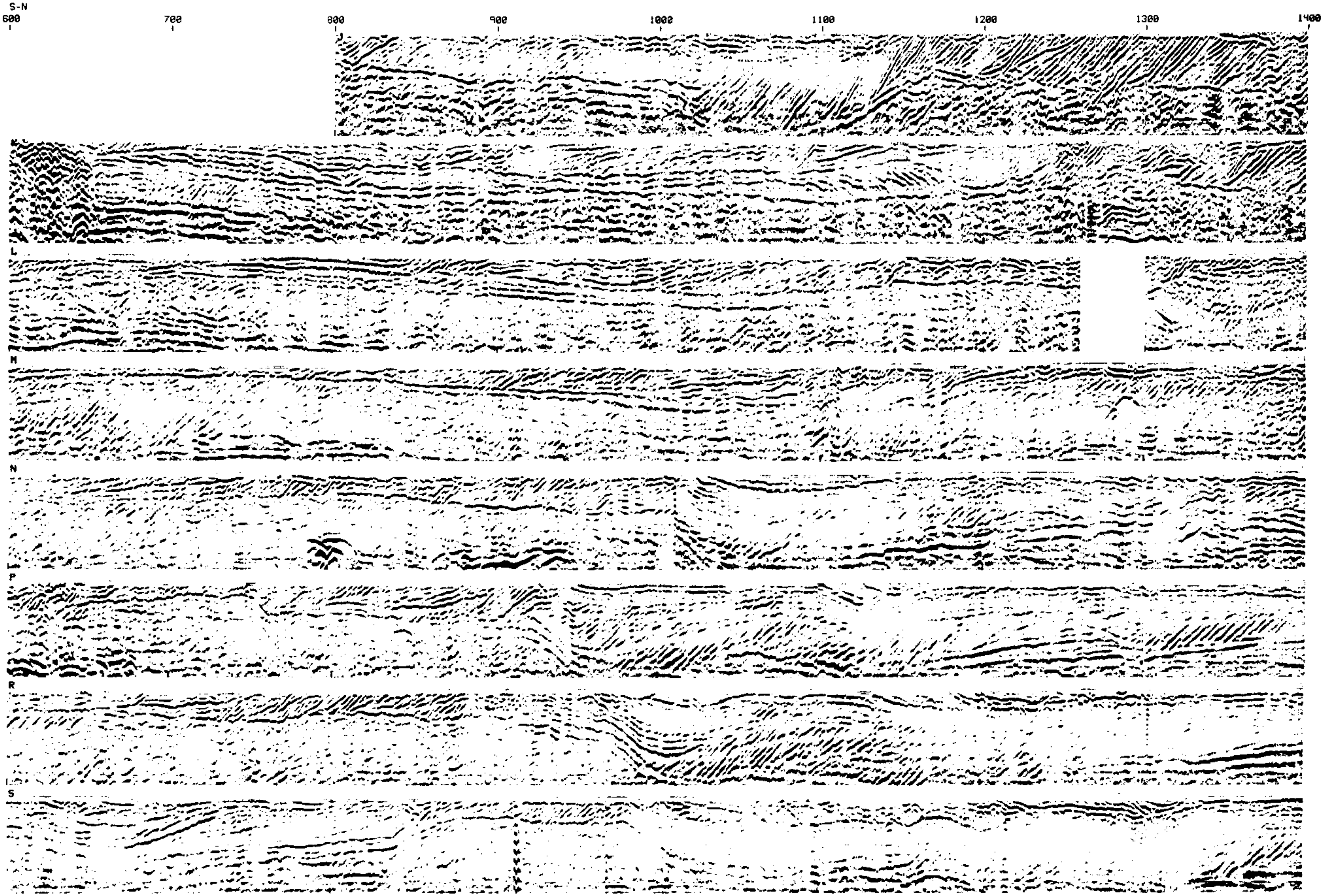
GPR PROFILES, HORN RAPIDS LANDFILL



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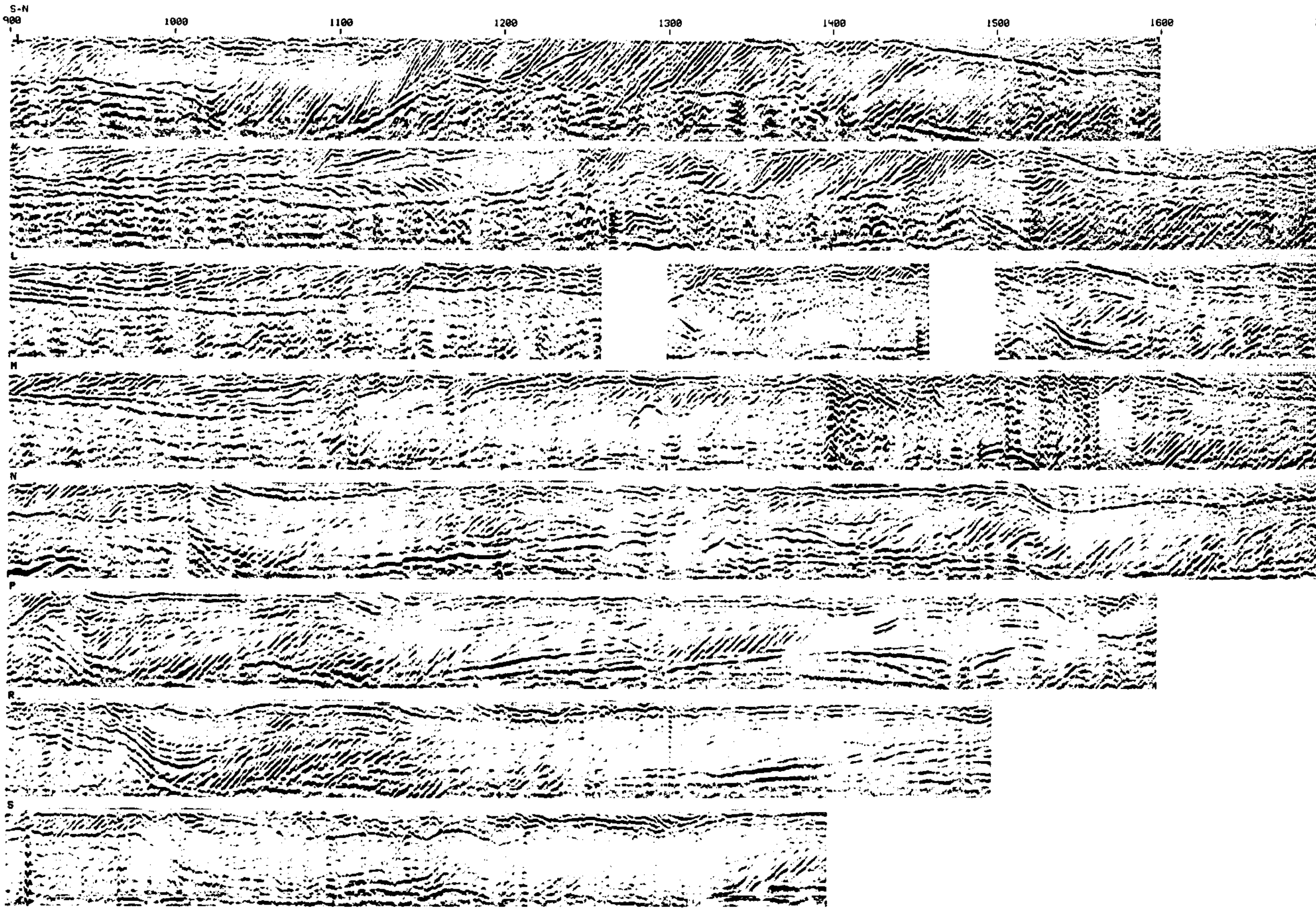

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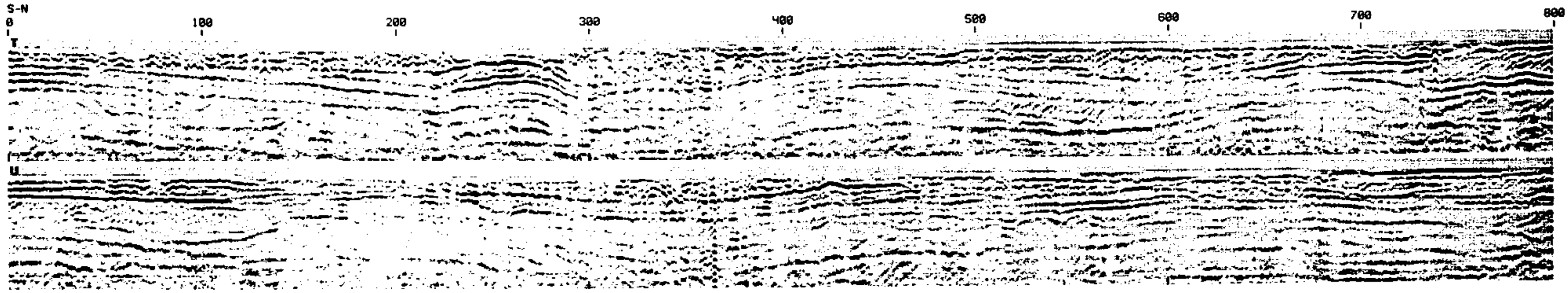

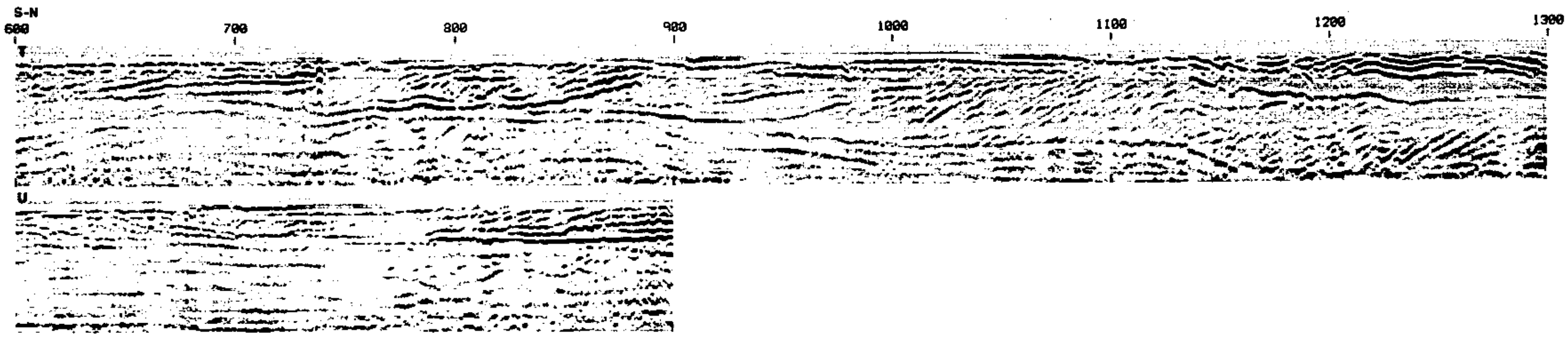

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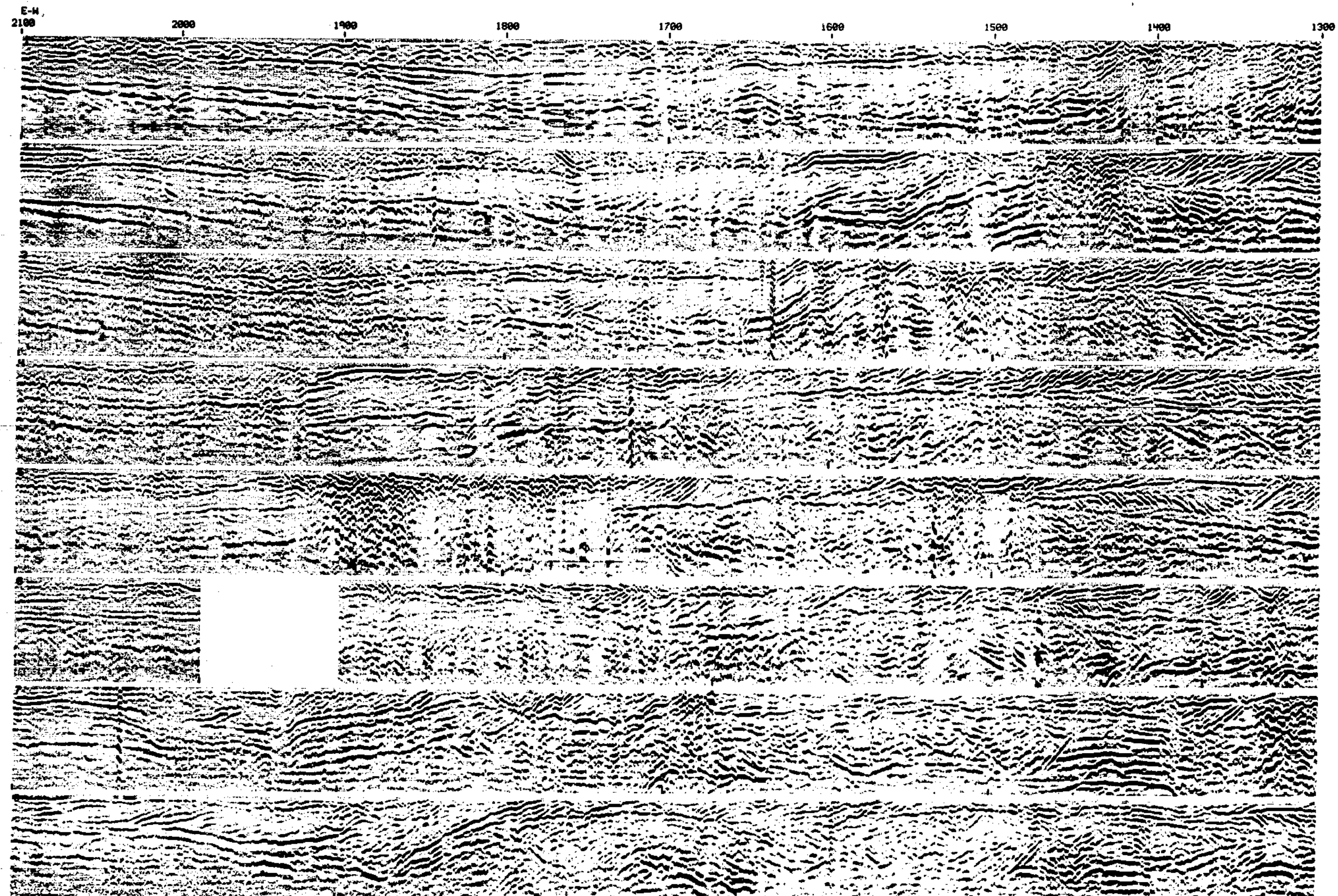

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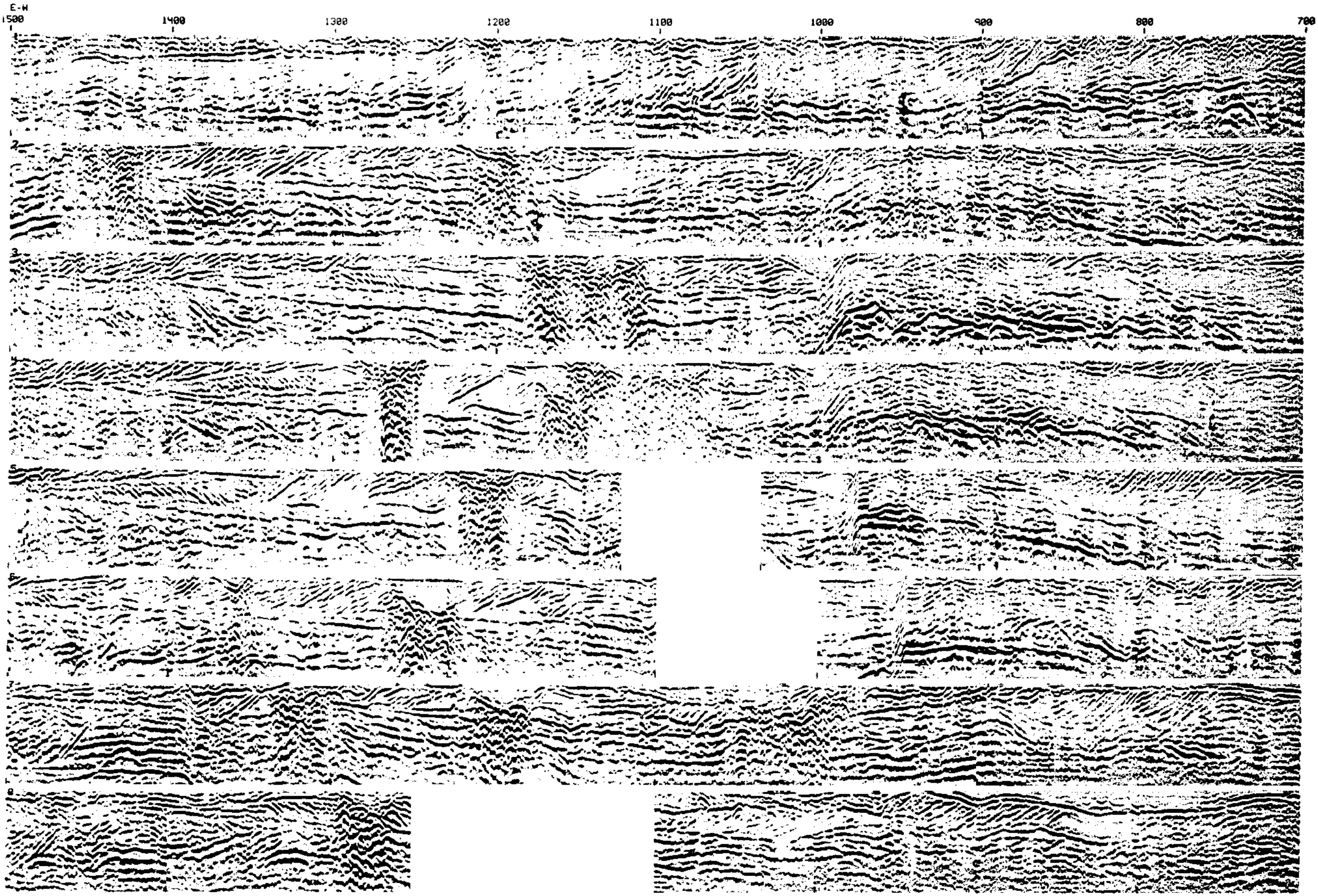

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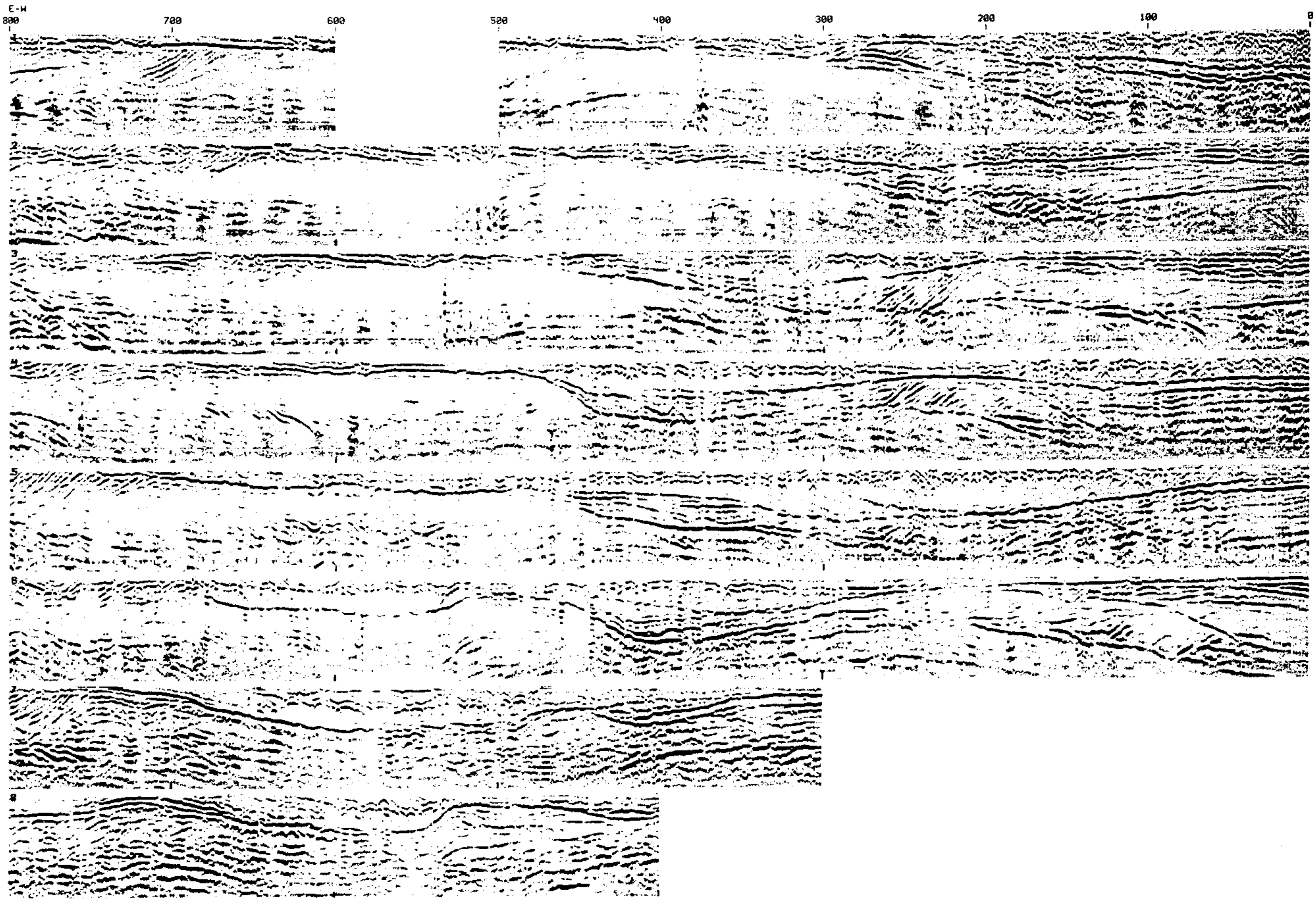

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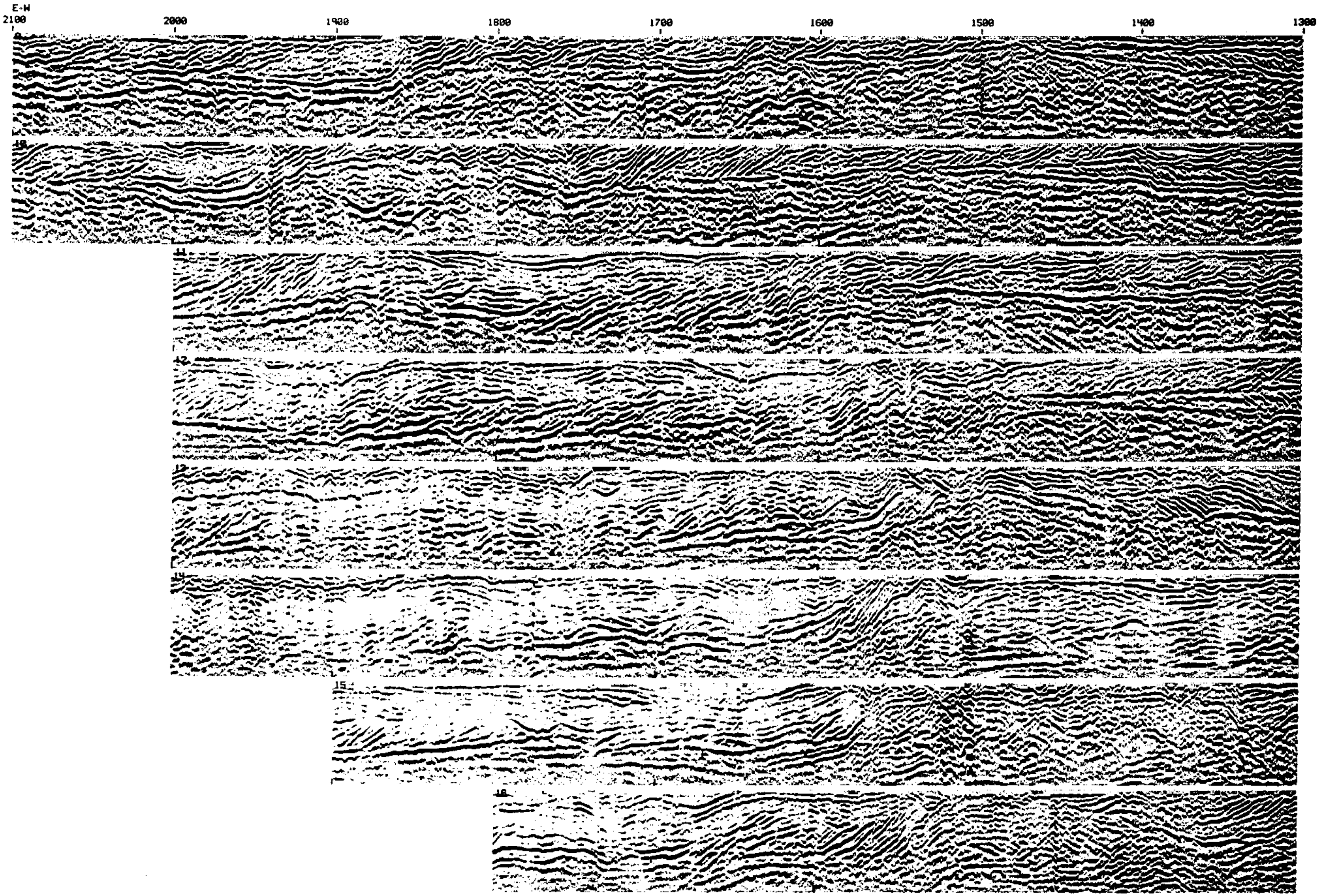

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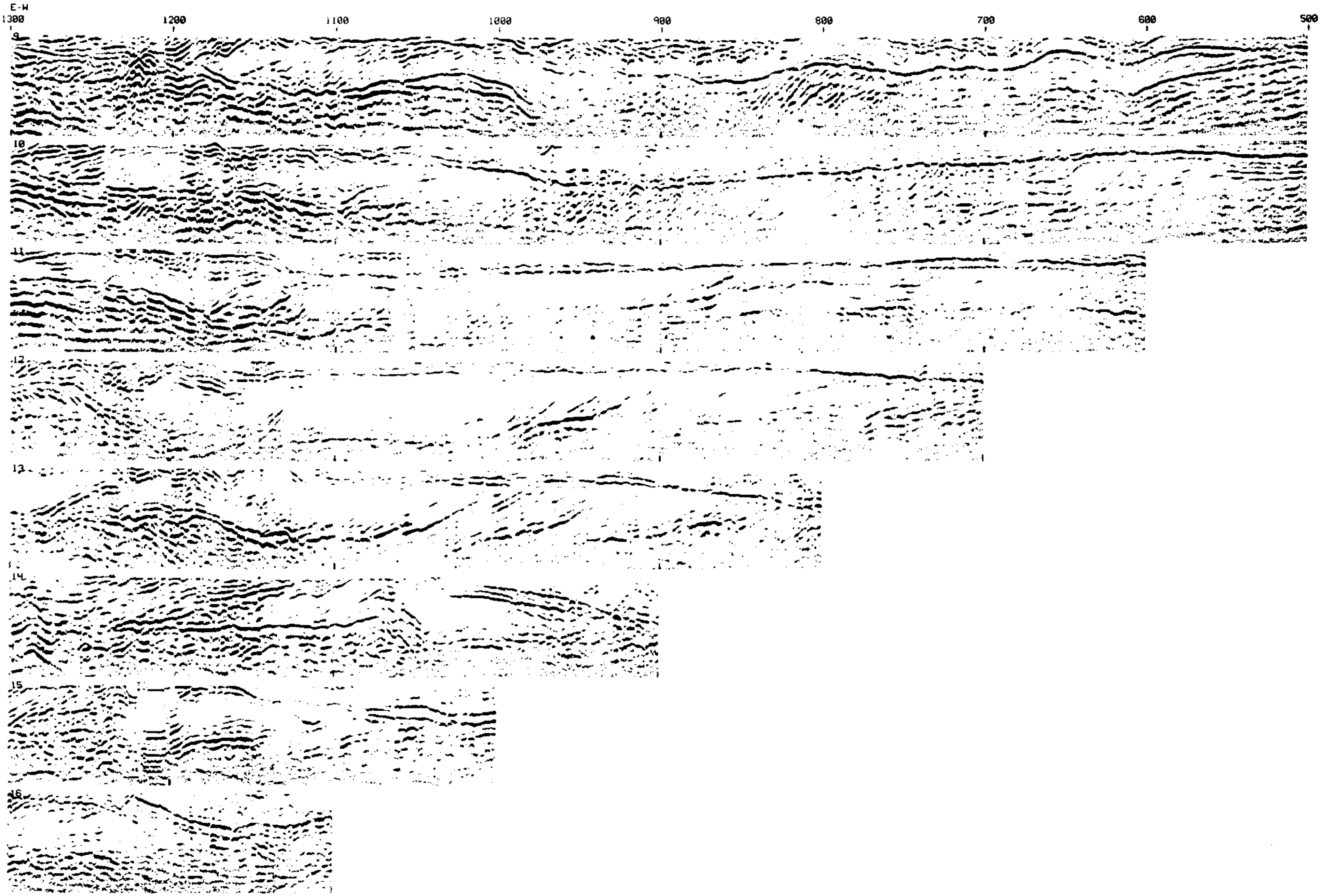

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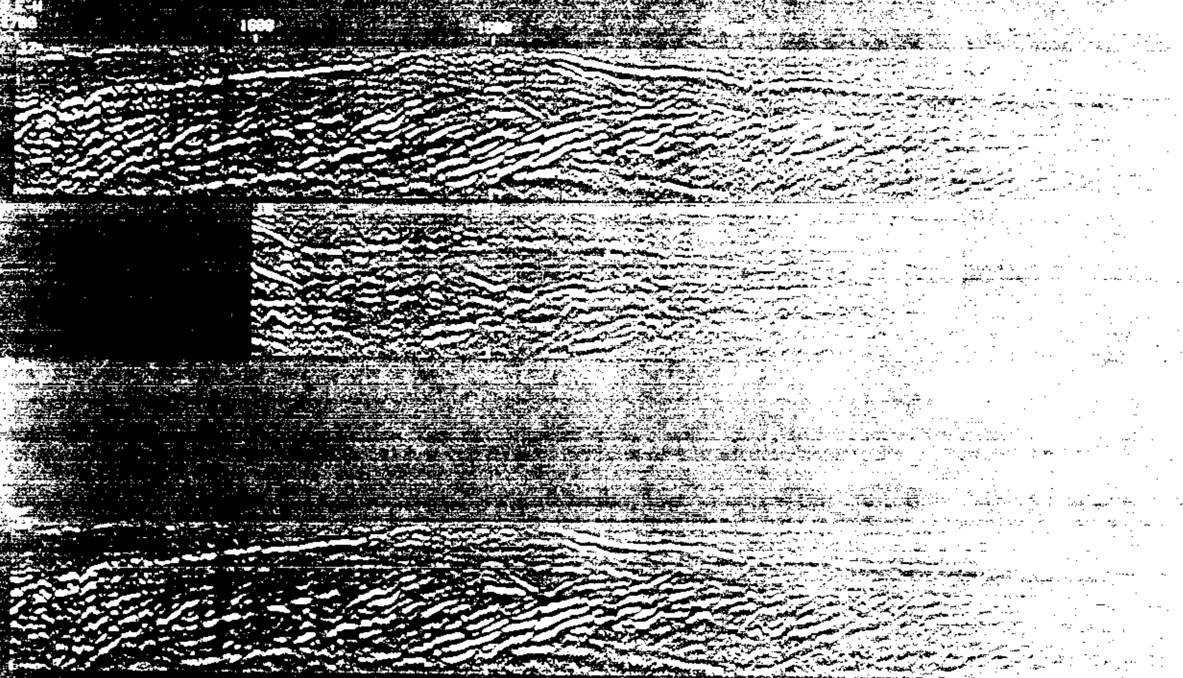

SITE MAPS

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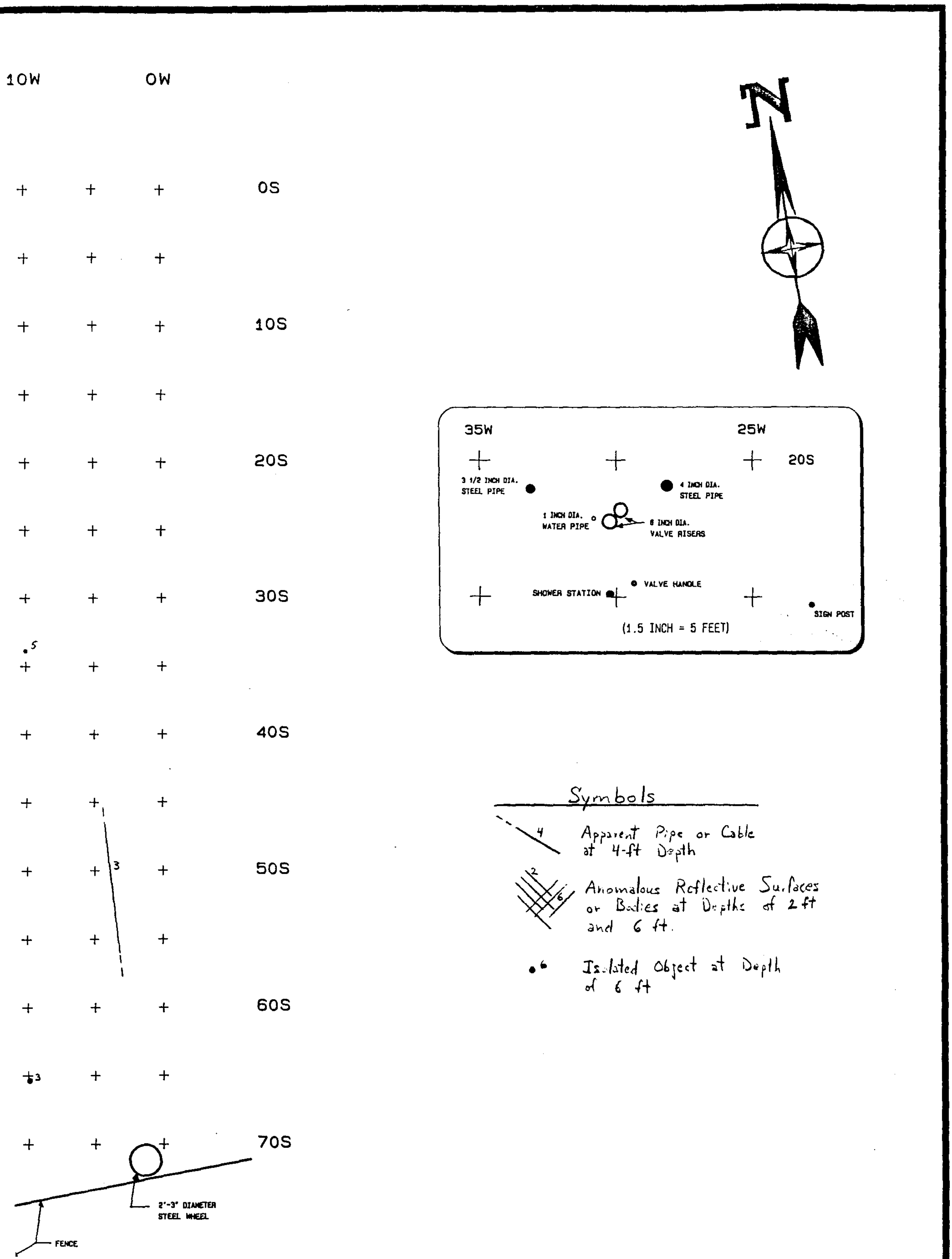


DATE 5/8/89

DRAWN BY GA Sandness

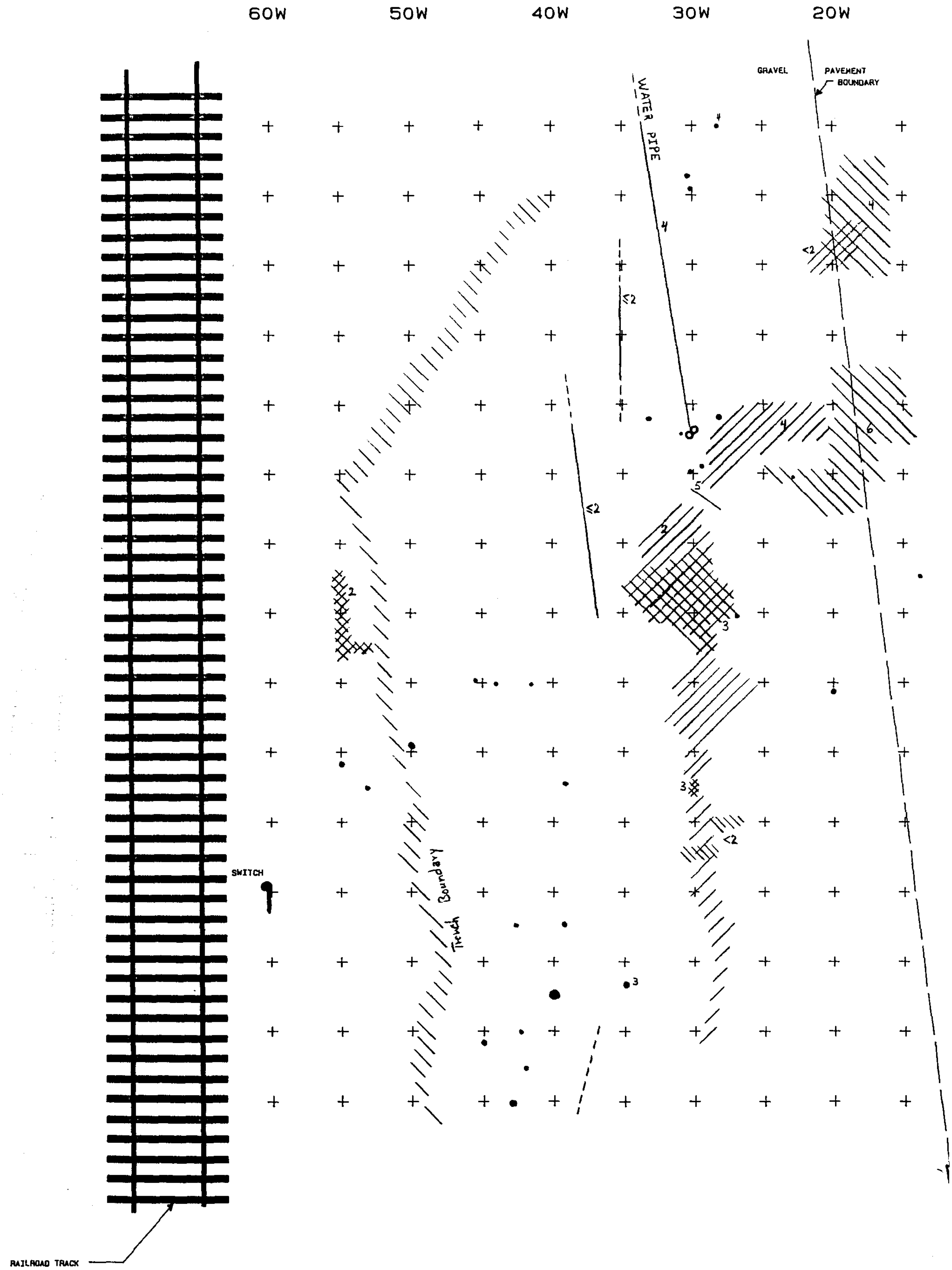
SCALE 0.75 Inch = 5 Feet

MAP NO

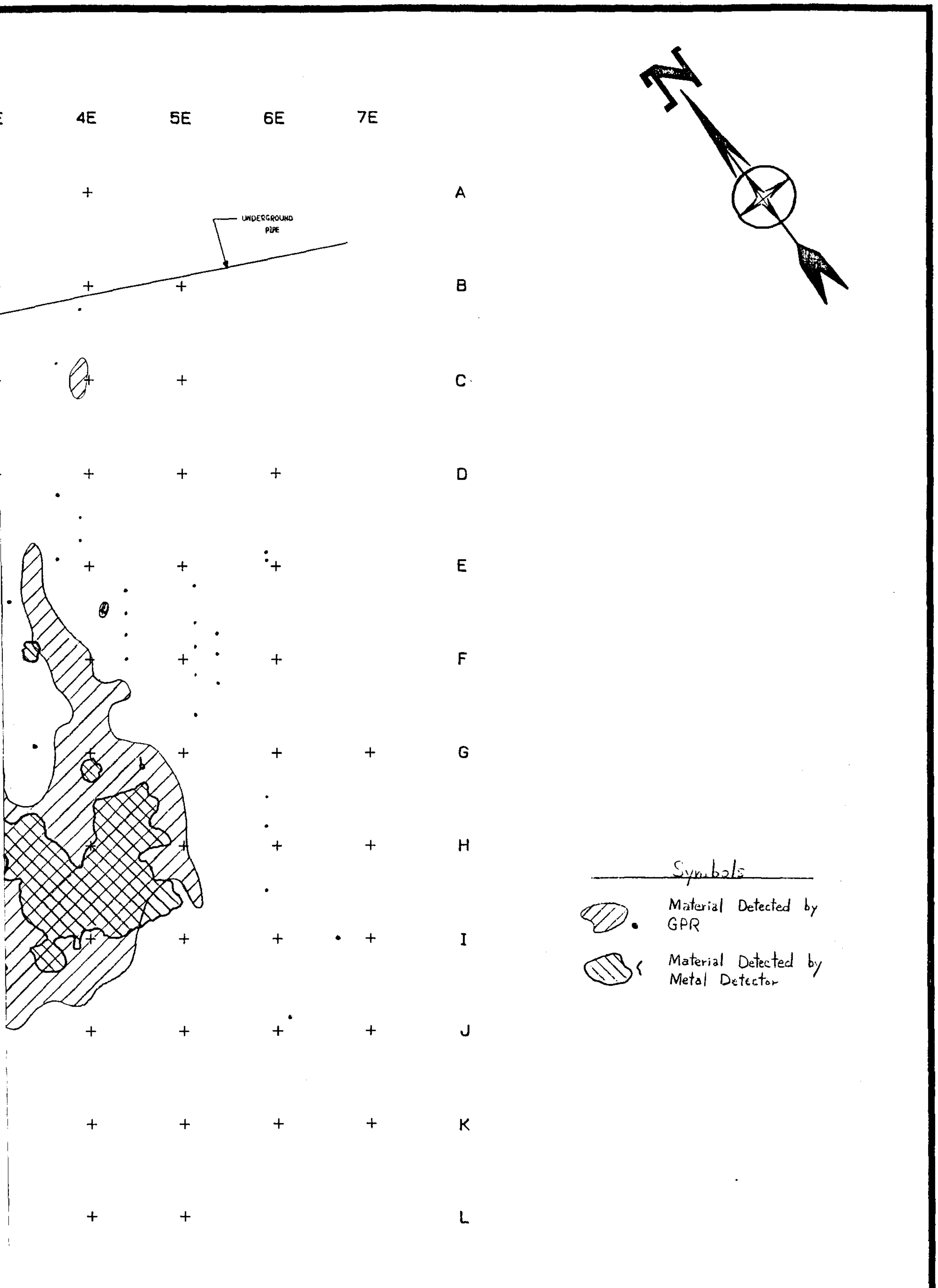
PACIFIC NORTHWEST LABORATORY
OPERATED BY BATTELLE MEMORIAL INSTITUTE

SUBSURFACE FEATURES LOCATED BY GPR AND METAL DETECTOR

OPERABLE UNIT



60W
50W
40W
30W
20W
GRAVEL
PAVEMENT
BOUNDARY
WATER PIPE
4
<2
≤2
≤2
4
5
6
2
2
3
3
<2
3
SWITCH
Trench Boundary
RAILROAD TRACK



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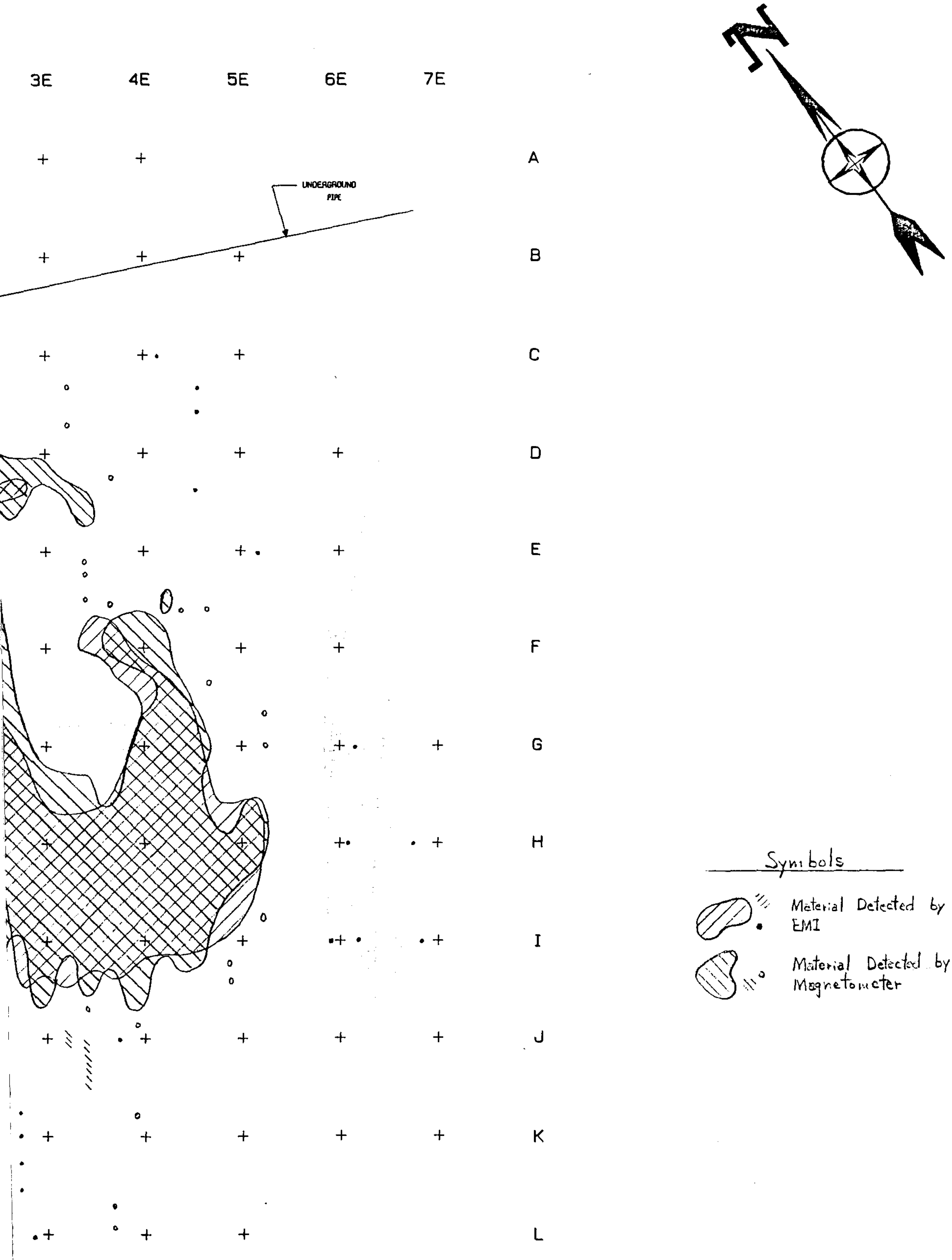
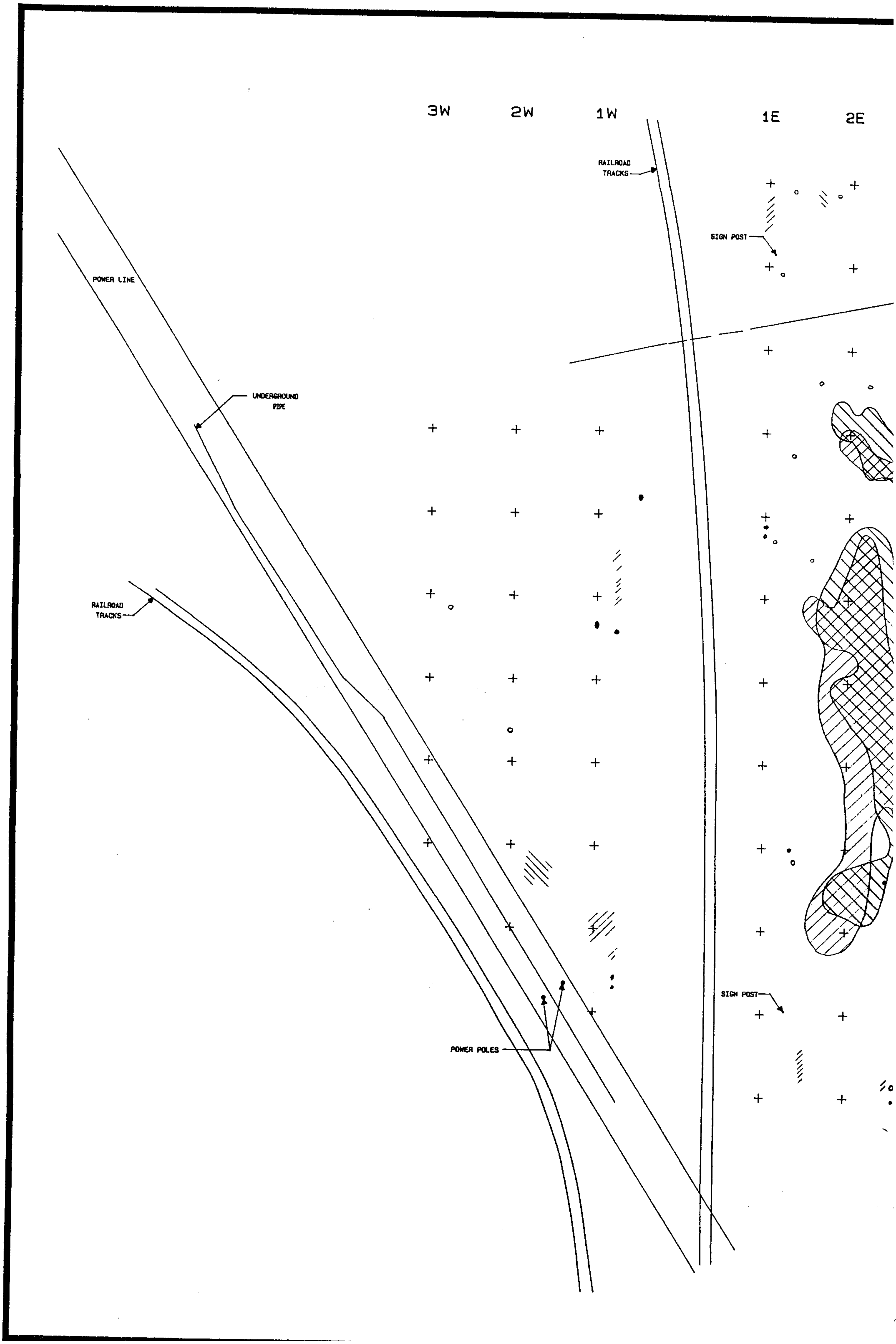
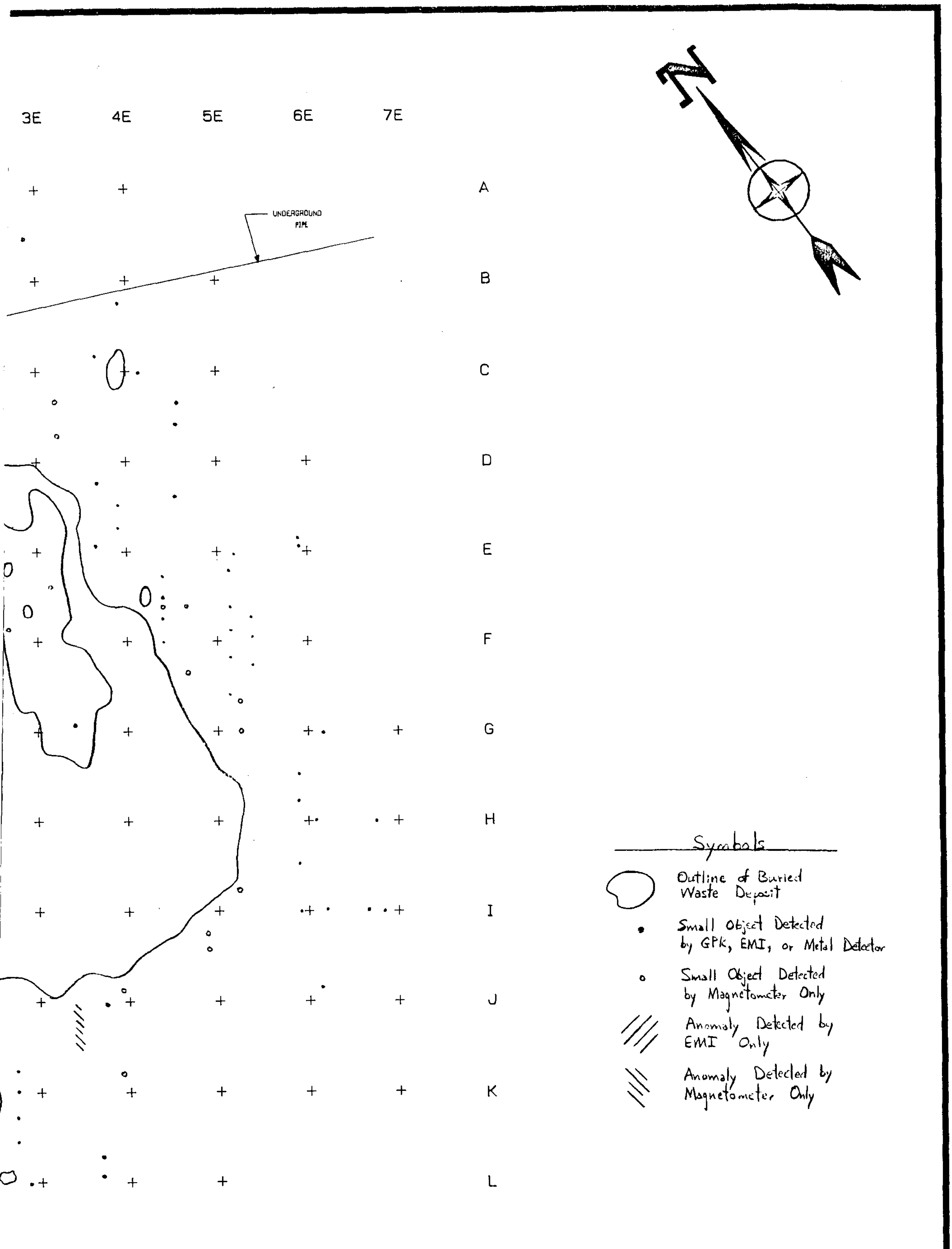
DRAWN BY GA Sandness	Buried Waste Materials Located by GPR and Metal Detector Surveys
SCALE 1 INCH = 40 FEET	

3W
2W
1W
1E
2E
3
RAILROAD TRACKS
SIGN POST
POWER LINE
UNDERGROUND PIPE
RAILROAD TRACKS
SIGN POST
POWER POLES

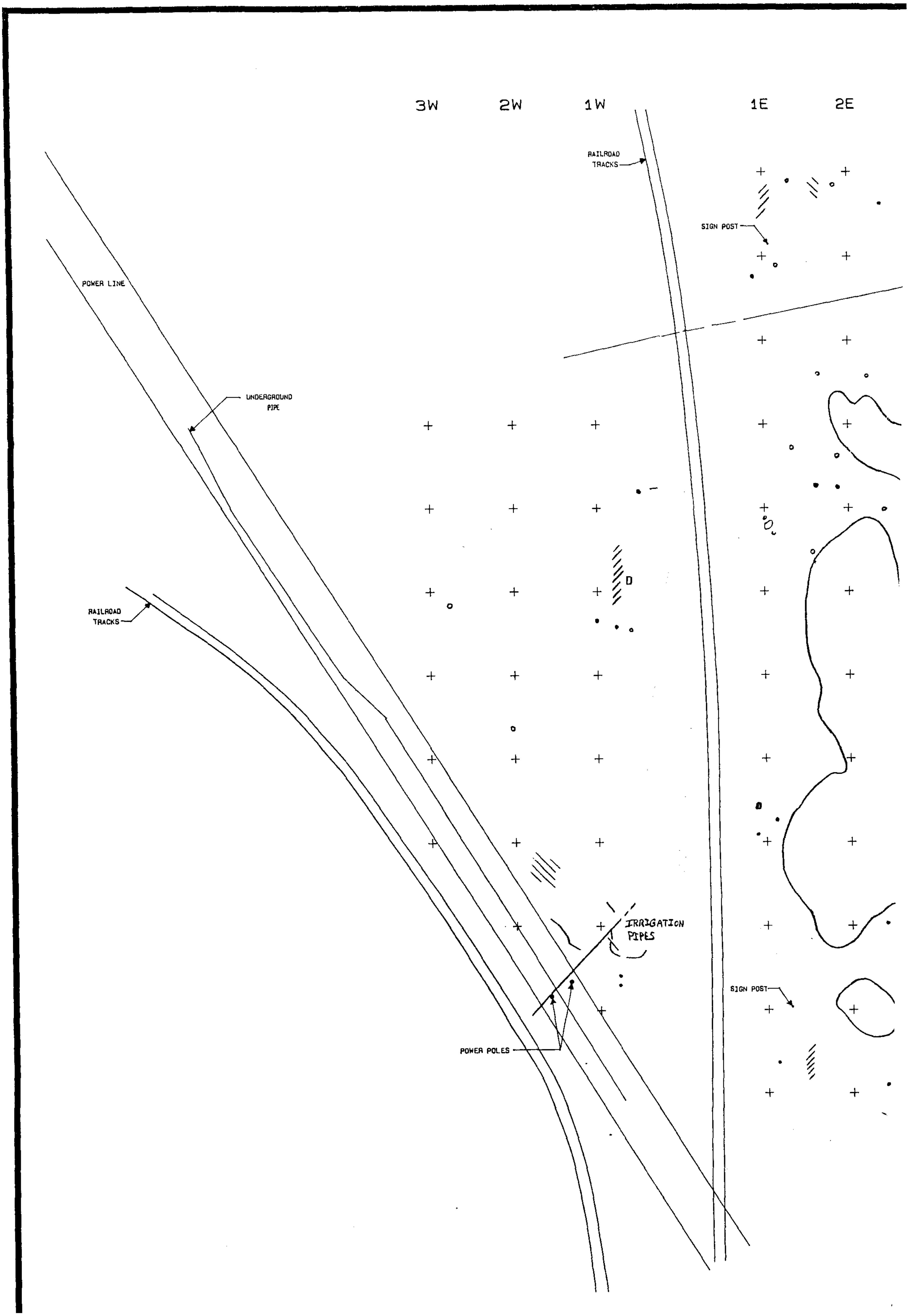


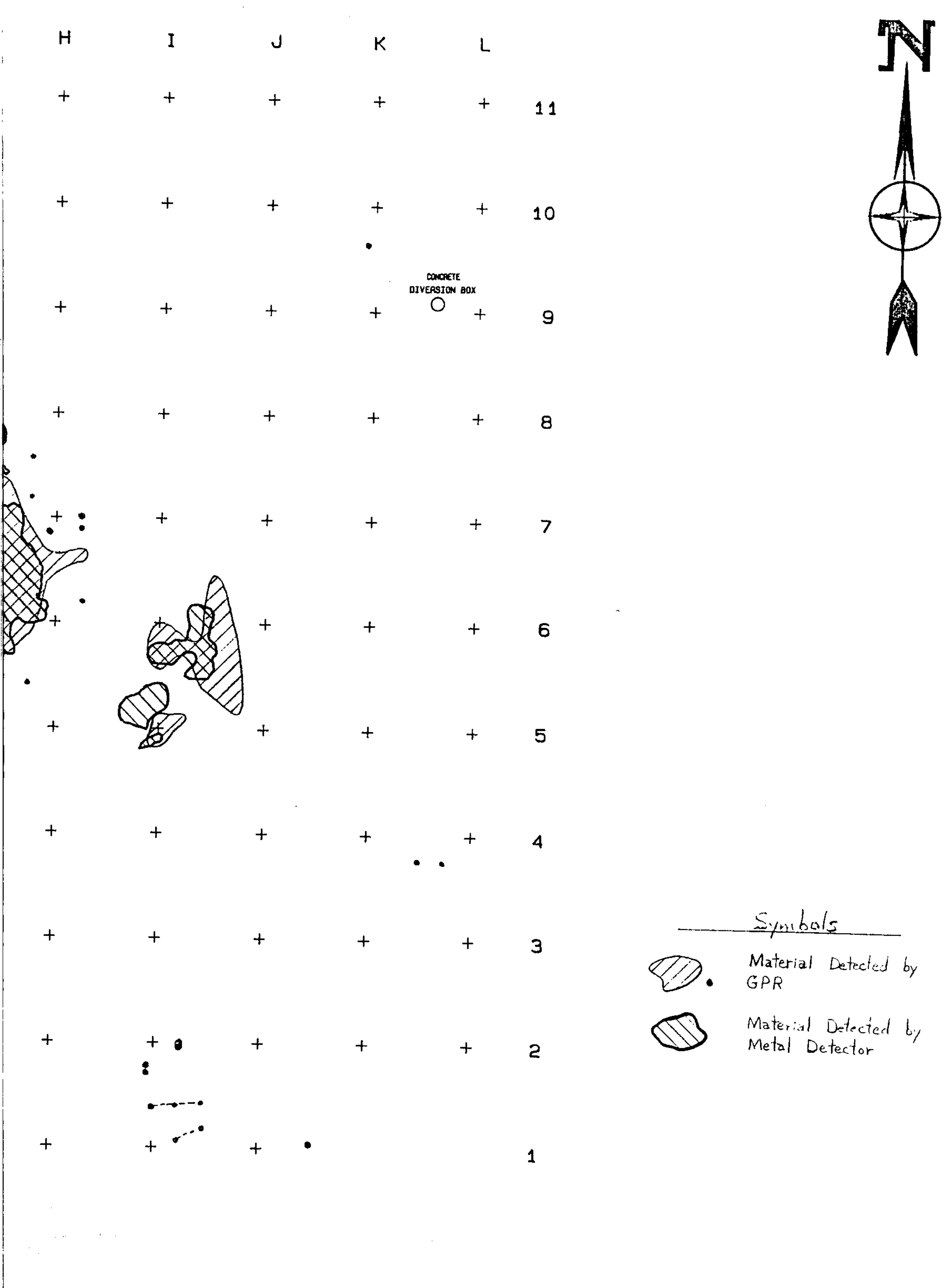
DATE 4/28/89	PACIFIC NORTHWEST LABORATORY OPERATED BY BATTELLE MEMORIAL INSTITUTE
DRAWN BY GA Sandness	Buried Waste Materials Located by EMI and Magnetic Surveys
SCALE 1 INCH = 40 FEET	
MAP NO.	OPERABLE UNIT / SITE


3W
2W
1W
1E
2E
RAILROAD TRACKS
SIGN POST
POWER LINE
UNDERGROUND PIPE
RAILROAD TRACKS
SIGN POST
POWER POLES



DATE 5/8/89	PACIFIC NORTHWEST LABORATORY OPERATED BY BATTELLE MEMORIAL INSTITUTE
DRAWN BY GA Sandness	Buried Waste Materials Located by Geophysical Surveys
SCALE 1 INCH = 40 FEET	
MAP NO. 4	OPERABLE UNIT 1100-EM-1 · SITE 1100-2


3W
2W
1W
1E
2E
RAILROAD TRACKS
SIGN POST
POWER LINE
UNDERGROUND PIPE
D
RAILROAD TRACKS
IRRIGATION PIPES
SIGN POST
POWER POLES



DATE 4/28/89	PACIFIC NORTHWEST LABORATORY OPERATED BY BATTELLE MEMORIAL INSTITUTE
DRAWN BY GA Sandness	Buried Waste Materials Located by GPR and Metal Detector Surveys
SCALE 1 INCH = 40 FEET	


A
B
C
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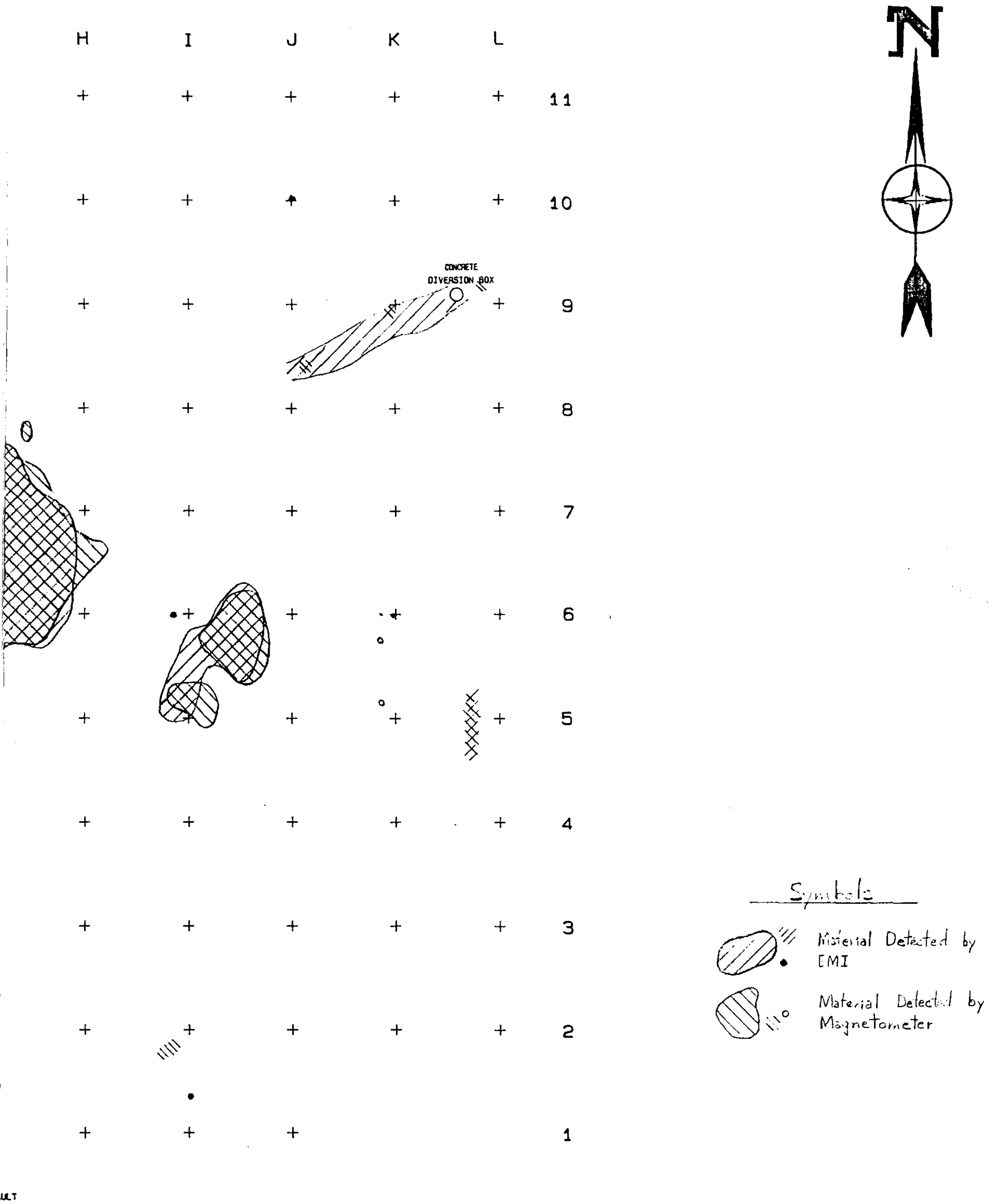
E
F
G
RAILROAD STORAGE YARD BOUNDARY
ROADWAY
UNDERGROUND POWER LINES
CONCRETE VAULT



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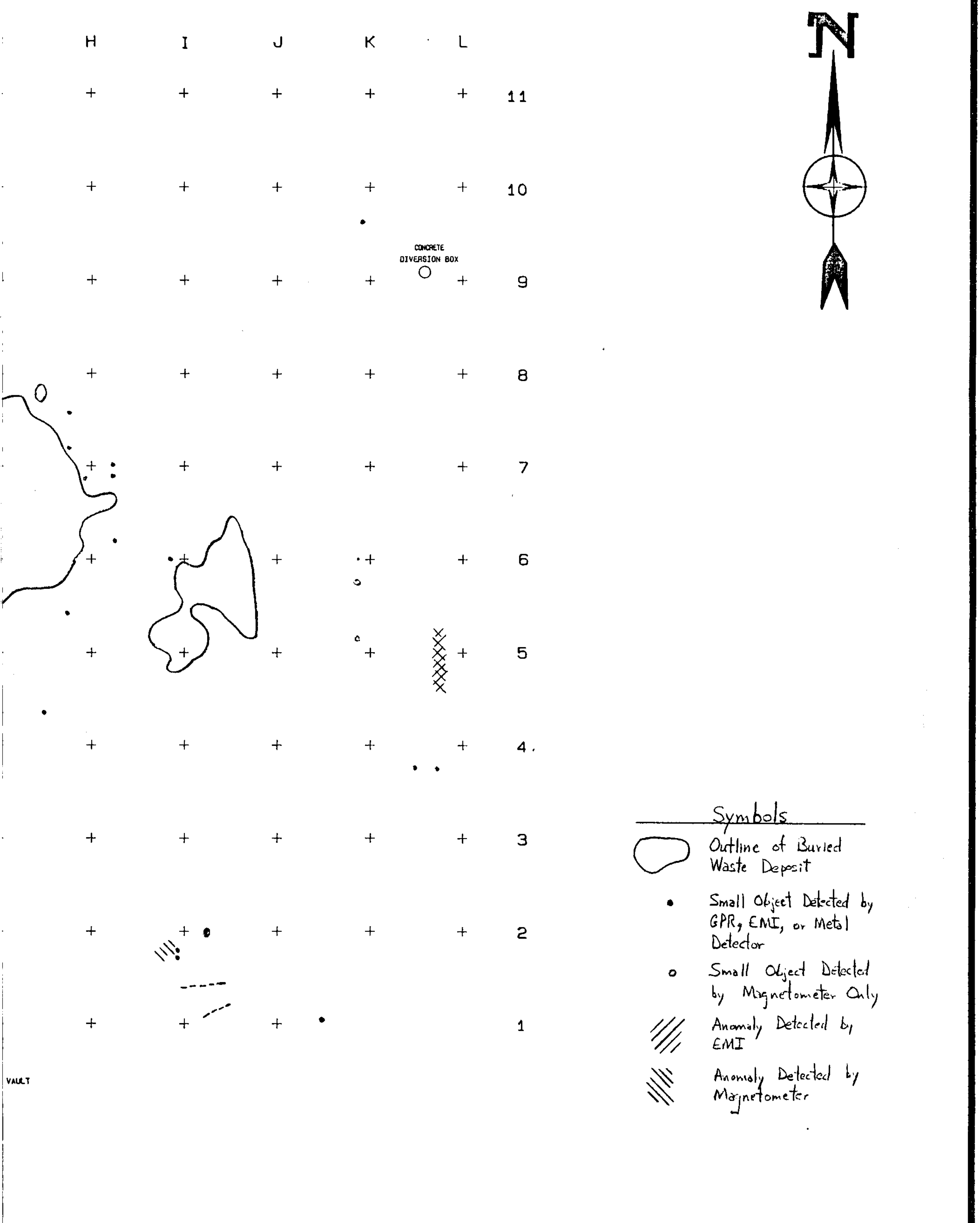
DRAWN BY GA Sandness	Buried Waste Materials Located by EMI and Magnetic Surveys
SCALE 1 INCH = 40 FEET	
MAP NO. /	OPERABLE UNIT · SITE


A
B
C
D
E
F
G
RAILROAD STORAGE
YARD BOUNDARY
ROADWAY
CONCRETE V
UNDERGROUND
POWER LINES



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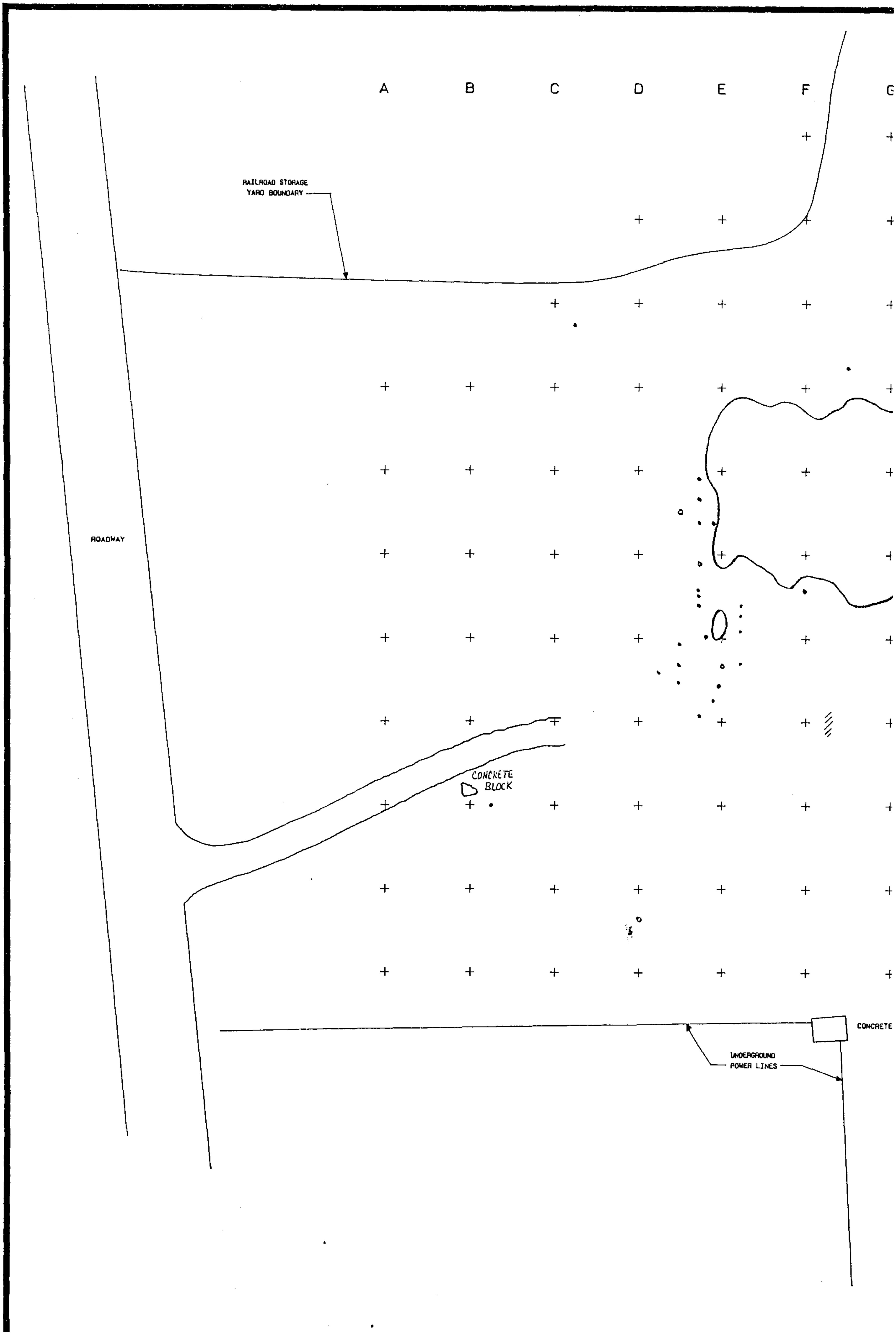
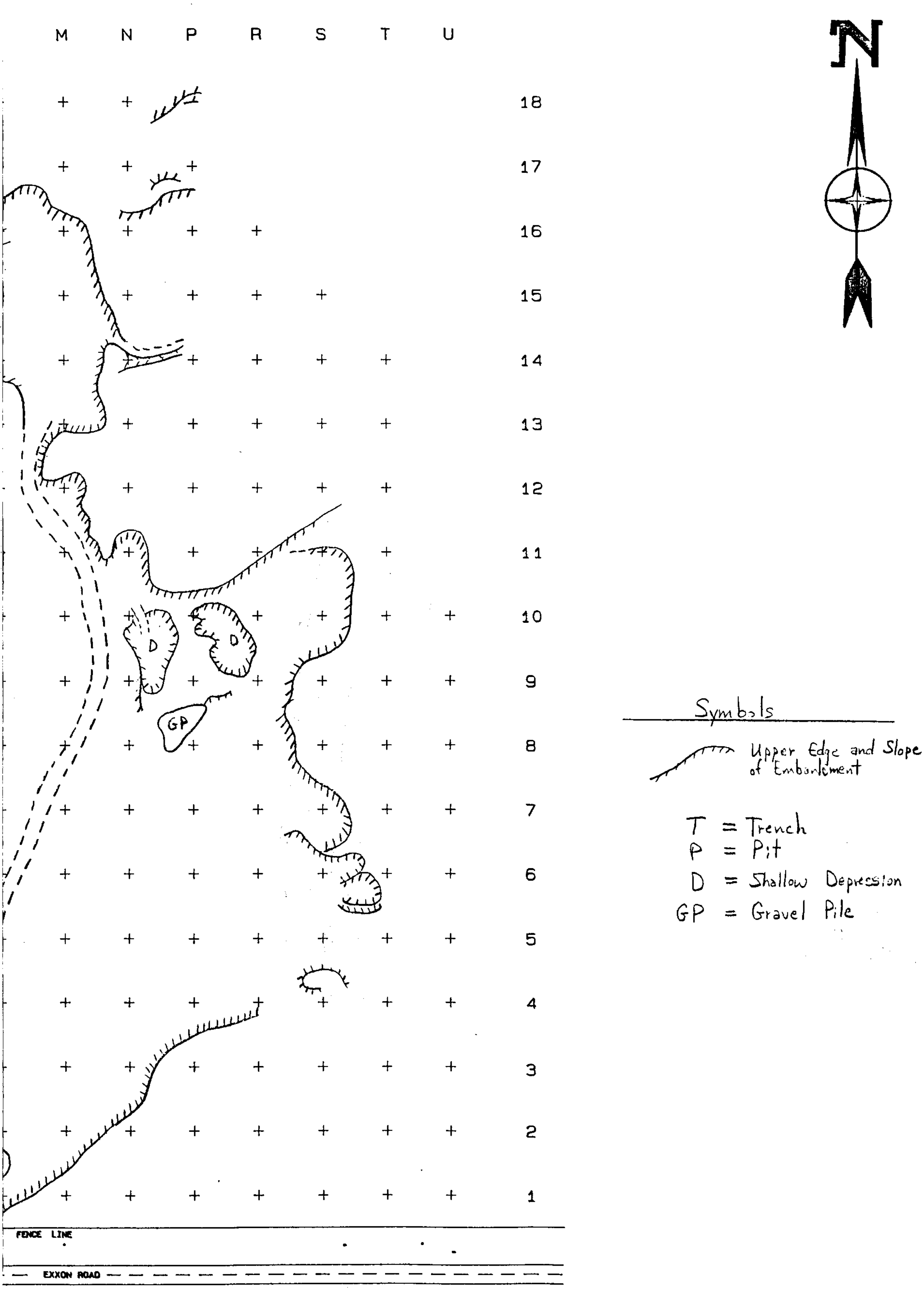
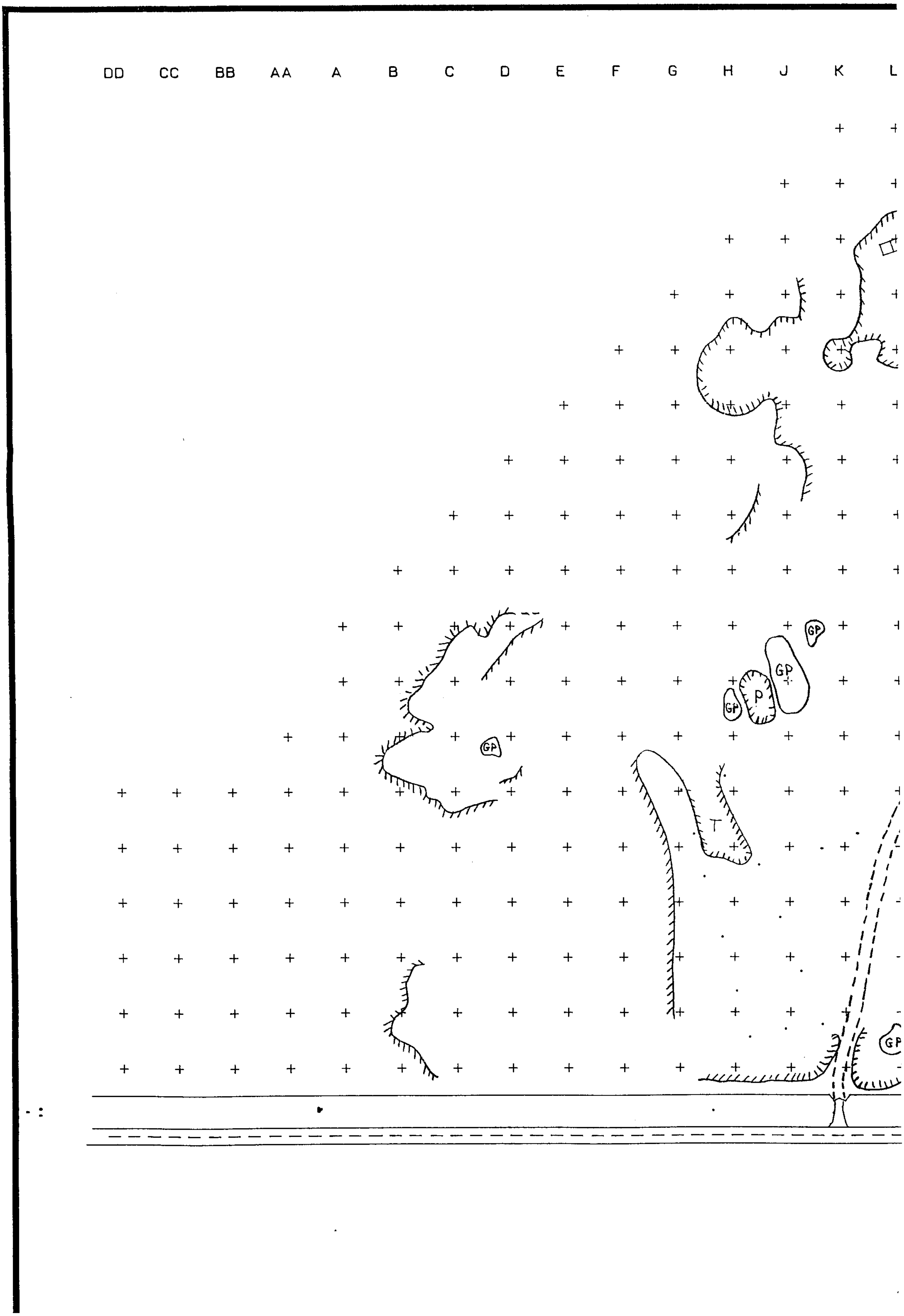
DRAWN BY GA Sandness	Buried Waste Materials Located by Geophysical Surveys	
SCALE 1 INCH = 40 FEET		
MAP NO. 7	OPERABLE UNIT	SITE


A
B
C
D
E
F
G
RAILROAD STORAGE YARD BOUNDARY
ROADWAY
CONCRETE BLOCK
CONCRETE
UNDERGROUND POWER LINES



DATE 4/13/89	PACIFIC NORTHWEST LABORATORY OPERATED BY BATTELLE MEMORIAL INSTITUTE
DRAWN BY GA Sandness	Topographic Features
SCALE 0.67 Inch = 100 Feet	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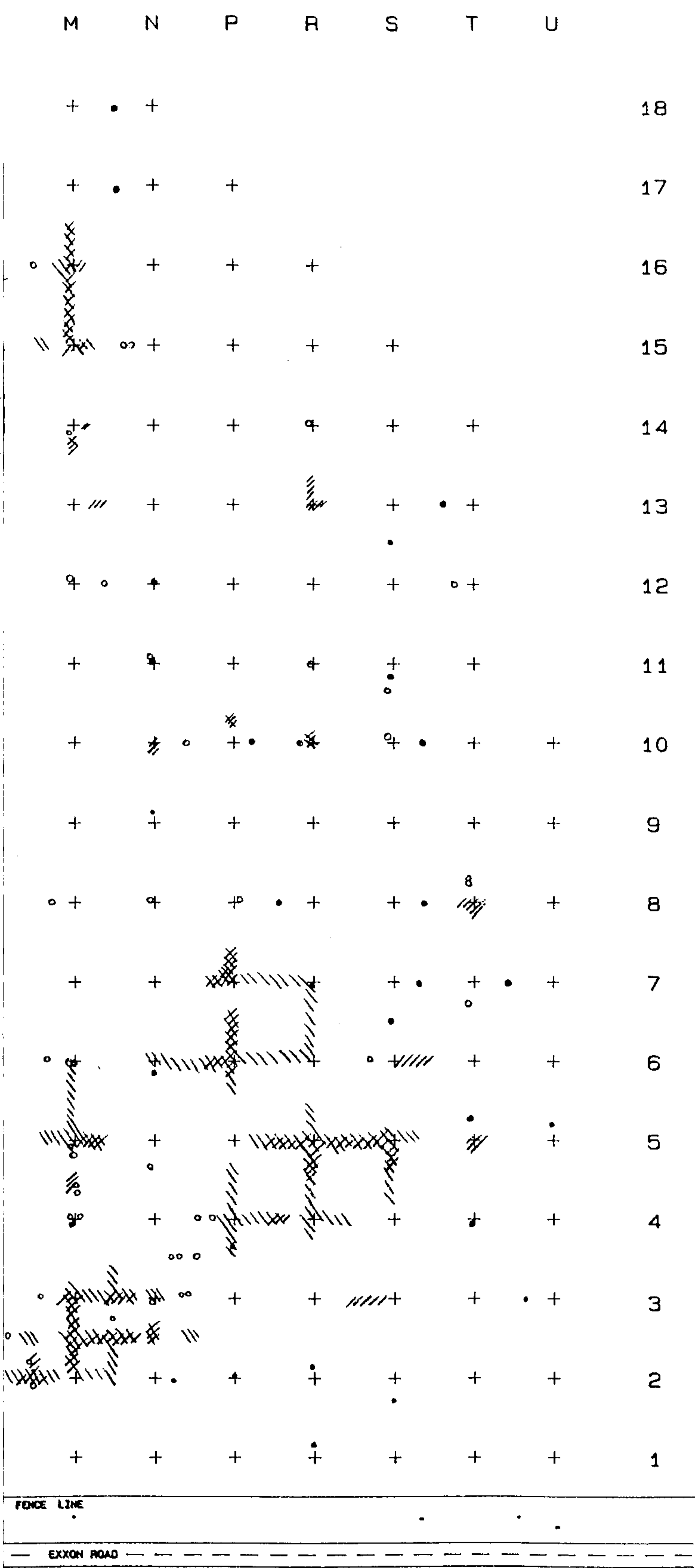

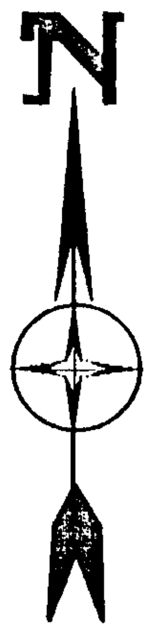

Symbols

Materials Located by EMI

Materials Located by GPR

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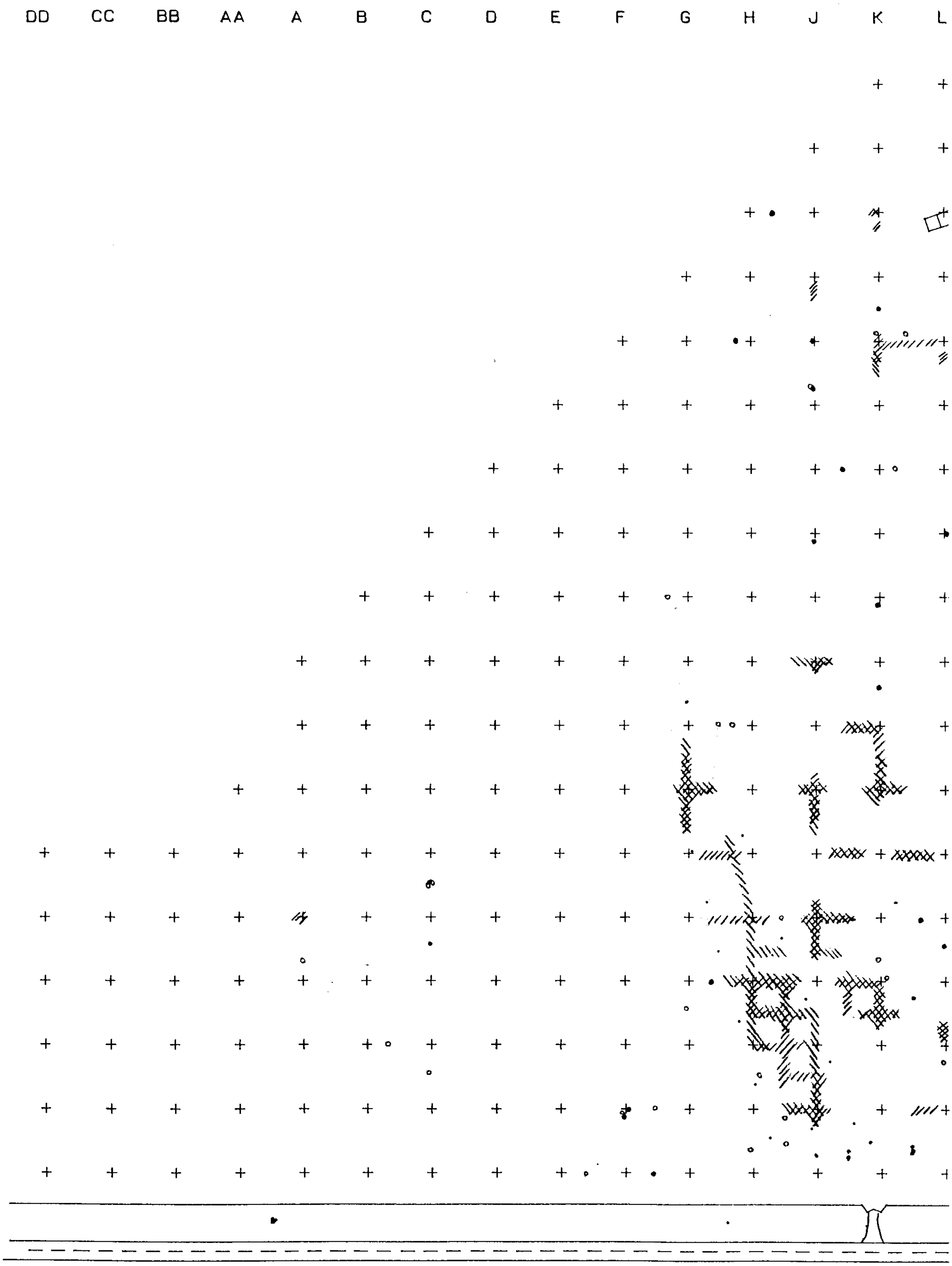
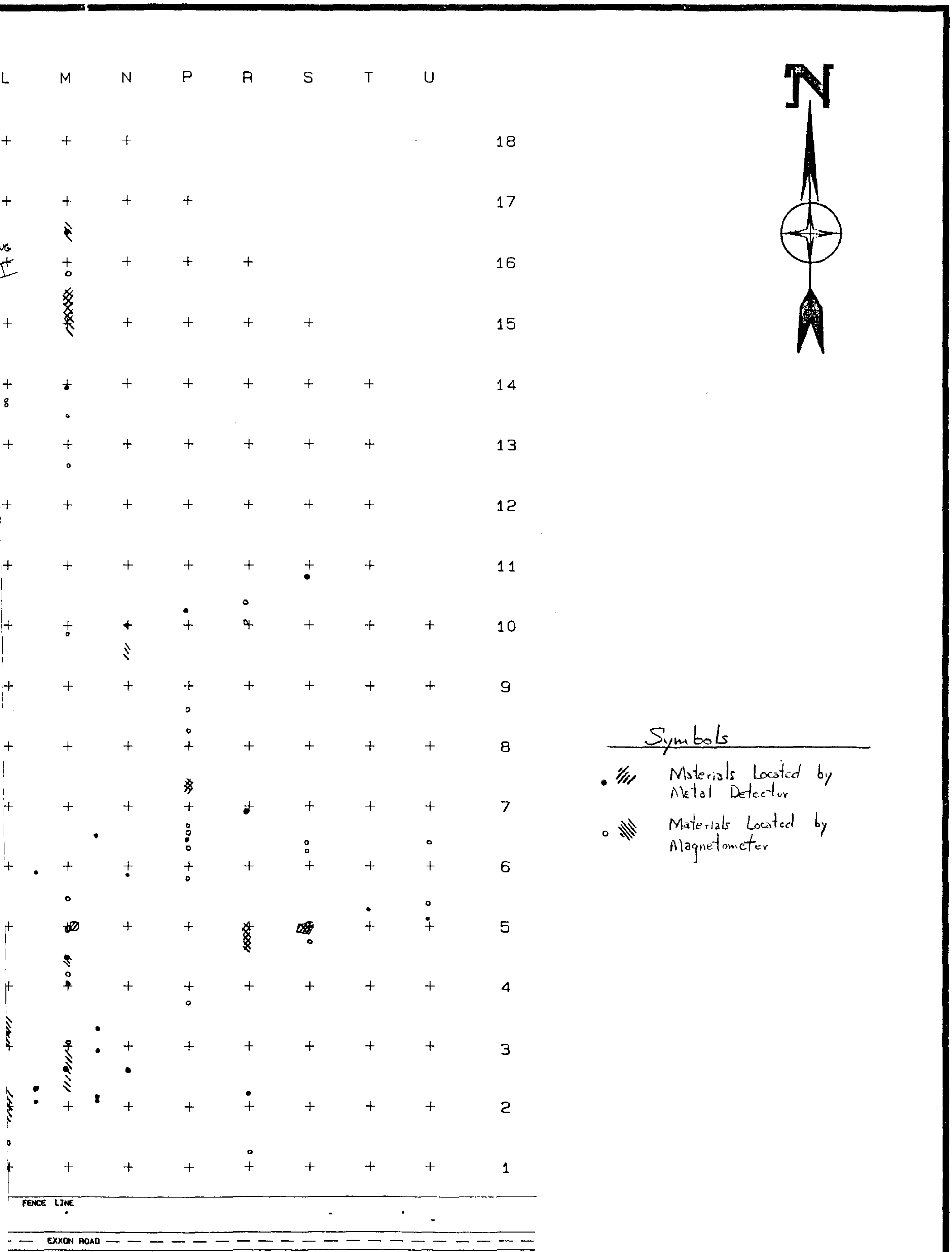
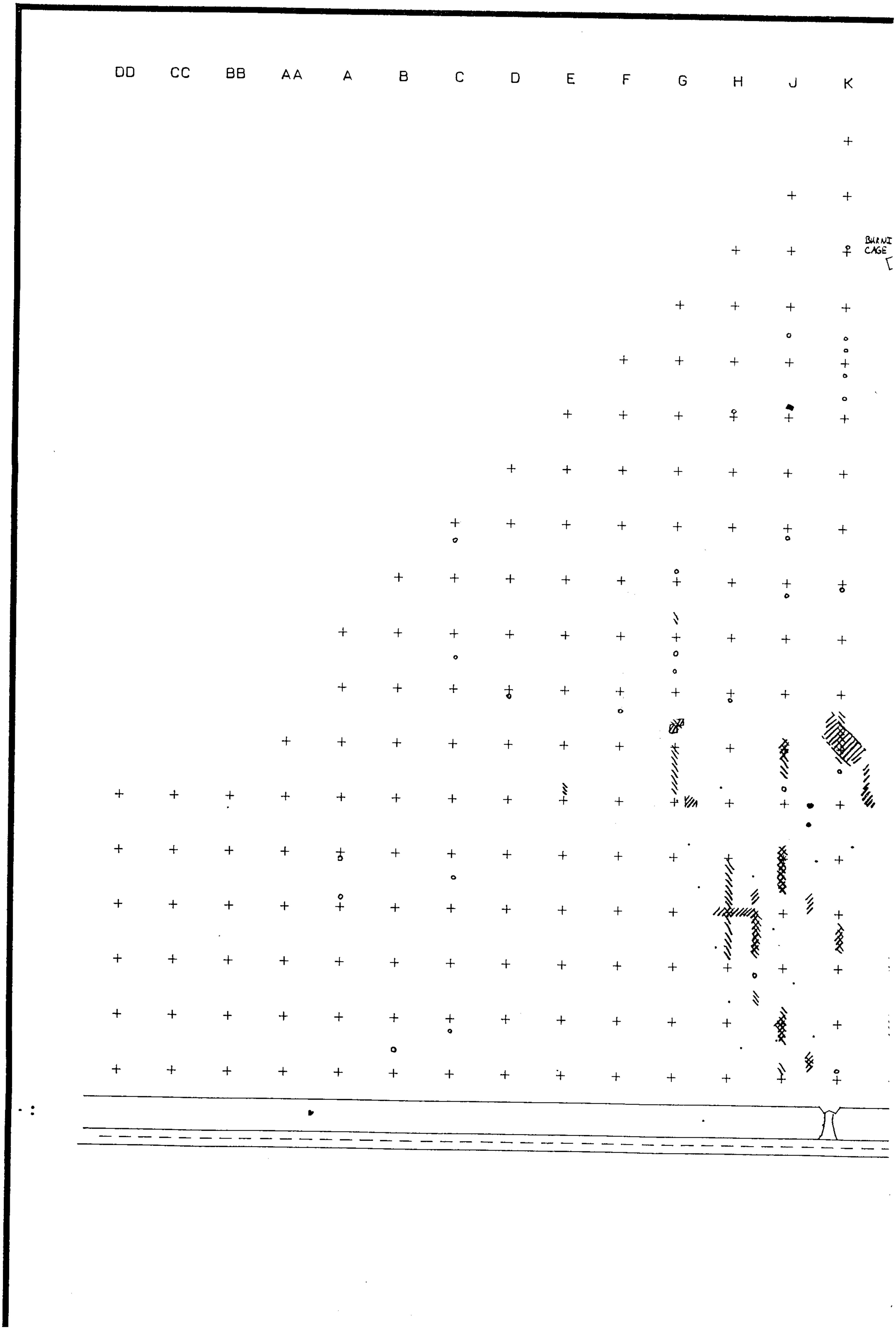
DRAWN BY GA Sandness	Buried Waste Materials Located by EMI and GPR
SCALE 0.67 Inch = 100 Feet	
MAP NO.	OPERABLE UNIT | SITE


DD CC BB AA A B C D E F G H J K L



DATE 4/29/89	PACIFIC NORTHWEST LABORATORY OPERATED BY BATTELLE MEMORIAL INSTITUTE
DRAWN BY GA Sandness	Buried Waste Materials Located by Metal Detector and Magnetometer
SCALE 0.67 Inch = 100 Feet	
MAP NO.	OPERABLE UNIT / SITE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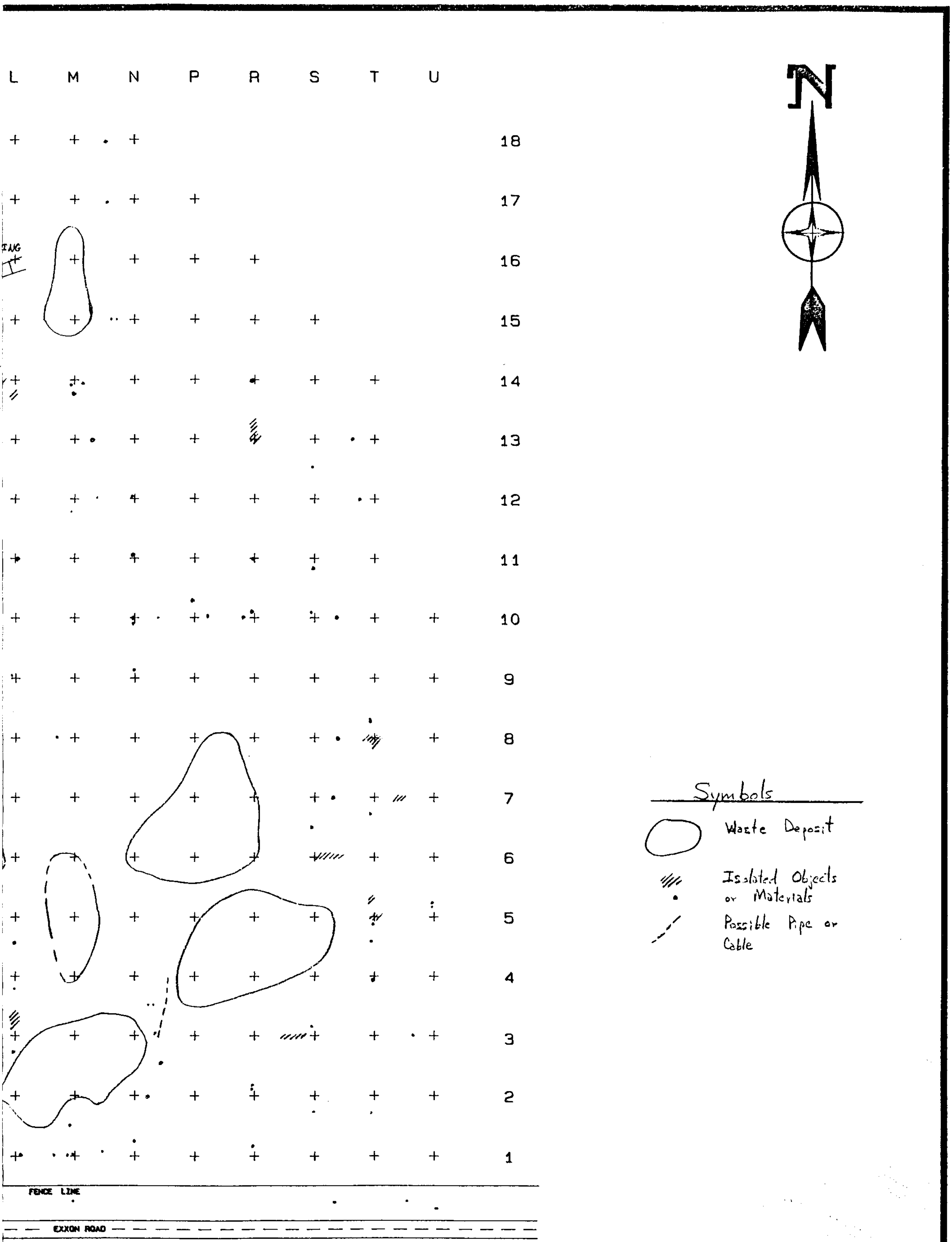
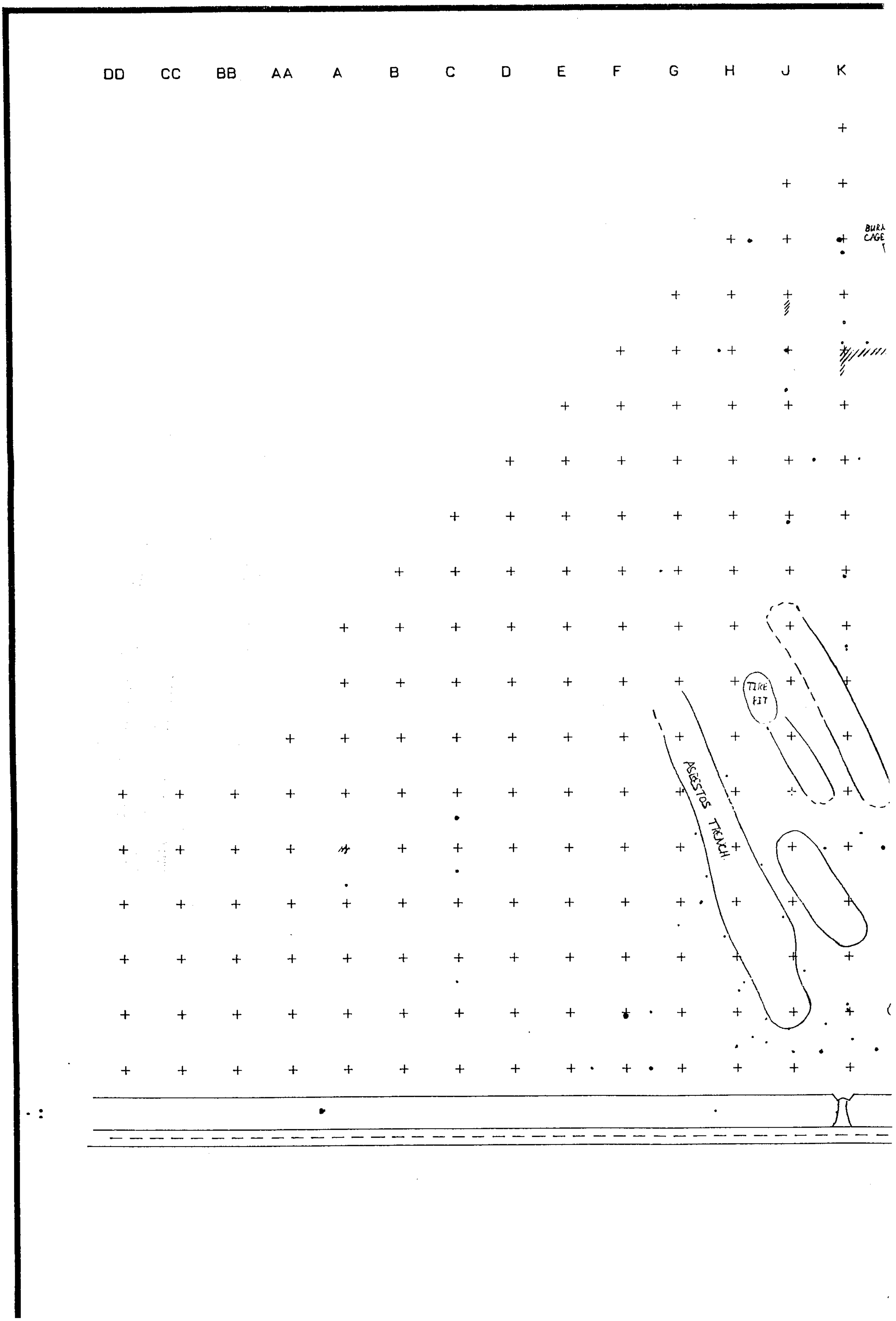


DATE 4/29/89	PACIFIC NORTHWEST LABORATORY OPERATED BY BATTELLE MEMORIAL INSTITUTE
DRAWN BY GA Sandness	Buried Waste Materials Located by Geophysical Surveys
SCALE 0.67 Inch = 100 Feet	

MAP NO.	OPERABLE UNIT	SITE
11	[illegible]	[illegible]



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